A Statistical Model Of Central Valley Chinook Incorporating Uncertainty

prepared by Lawrence, Cathy

submitted to Science Program 2004

compiled 2005−01−06 16:46:42 PST

Project

This proposal is for the Science Program 2004 solicitation as prepared by Lawrence, Cathy .

The submission deadline is 2005−01−06 17:00:00 PST (approximately 13 minutes from now).

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Instructions

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Proposal Title	***A Statistical Model of Central Valley Chinook Incorporating Uncertainty***	
Institutions	University of California, Davis R2 Resource Consultants NOAA Fisheries	*List each institution involved, one per line.*
Proposal Document		*You have already uploaded a proposal document. View it to verify that it appears as you expect. You may replace it by uploading another document*
Project Duration	***36 months***	

Is the start date a determining factor to the successful outcome of the proposed effort?
X No.
− Yes. Anticipated start date of this effort: ***2006−01−01***

Select all of the following study topics which apply to this proposal.
X life cycle models and population biology of key species
X environmental influences on key species and ecosystems
X relative stresses on key fish species
− direct and indirect effects of diversions on at−risk species
− processes controlling Delta water quality
X implications of future change on regional hydrology, water operations, and environmental processes
− water management models for prediction, optimization, and strategic assessments
− assessment and monitoring
X salmonid−related projects
− Delta smelt−related projects

Select as many keywords as necessary to describe this proposal (minimum of 3).
X adaptive management
− aquatic plants
− benthic invertebrates
− biological indicators
− birds
− neotropical migratory birds
− shorebirds
− upland birds
− wading birds
− waterfowl
X climate
X climate change
− precipitation
− sea level rise
− snowmelt
− contaminants / toxicants / pollutants
− contaminants and toxicity of unknown origin
− emerging contaminants
− mercury

− nutrients and oxygen depleting substances
− organic carbon and disinfection byproduct precursors
− persistent organic contaminants
− pesticides
− salinity
− sediment and turbidity
− selenium
− trace metals
− ***database management***
− ***economics***
− ***engineering***
− civil
− environmental
− hydraulic
− ***environmental education***
− ***environmental impact analysis***
− ***environmental laws and regulations***
− ***environmental risk assessment***
− ***fish biology***
− bass and other centarchids
− delta smelt
− longfin smelt
− other species
X salmon and steelhead
− splittail
− striped bass
− sturgeon
− ***fish management and facilities***
− hatcheries
− ladders and passage
− screens
− ***forestry***
− ***genetics***
− ***geochemistry***
− ***geographic information systems (GIS)***
− ***geology***
− ***geomorphology***
− ***groundwater***
X habitat
− benthos
− channels and sloughs
− flooded islands
− floodplains and bypasses
X oceanic
− reservoirs
− riparian
X rivers and streams
− shallow water
− upland habitat
− vernal pools
− water column
− wetlands, freshwater
− wetlands, seasonal
− wetlands, tidal
− ***human health***
X hydrodynamics
− ***hydrology***
− ***insects***
− ***invasive species / non−native species / exotic species***
− ***land use management, planning, and zoning***
− ***limnology***
− ***mammals***
− large
− small
− ***microbiology / bacteriology***

X modeling
X conceptual
X quantitative
− ***monitoring***
X natural resource management
X performance measures
− ***phytoplankton***
− ***plants***
− ***primary productivity***
− ***reptiles***
− ***restoration ecology***
− ***riparian ecology***
− ***sediment***
− ***soil science***
X statistics
− ***subsidence***
− ***trophic dynamics and food webs***
X water operations
− barriers
− diversions / pumps / intakes / exports
− gates
− levees
− reservoirs
− ***water quality management***
− ag runoff
− mine waste assessment and remediation
− remediation
− temperature
− urban runoff
− water quality assessment and monitoring
− ***water resource management***
− ***water supply***
− demand
− environmental water account
− water level
− water storage
− ***watershed management***
− ***weed science***
− ***wildlife***
− ecology
− management
− wildlife−friendly agriculture
− ***zooplankton***
− ***administrative***

Indicate whether your project area is local, regional, or system−wide. If it is local, provide a central ZIP Code. If it is regional, provide the central ZIP Code and choose the counties affected. If it is system−wide, describe the area using information such as water bodies, river miles, and road intersections.	
− local	ZIP Code:
− regional	ZIP Code: counties:
X system−wide	This project contains models of the entire life−cycle of Central Valley chinook salmon. As such, it will incorporate information from spawning areas, the main stem of the Sacramento River, the Bay−Delta and the Pacific Ocean.

Does your project fall on or adjacent to tribal lands?
No.

(Refer to California Indian reservations to locate tribal lands.)
If it does, list the tribal lands.

Has a proposal for this effort or a similar effort ever been submitted to CALFED for funding or to any other public agency for funding?
No.

If yes, complete the table below.

Status	Proposal Title	Funding Source	Amount	Comments

Has the lead scientist or principal investigator of this effort ever submitted a proposal to CALFED for funding or to any other public agency for funding?
Yes.

If yes, provide the name of the project, when it was submitted, and to which agency and funding mechanism if was submitted. Also describe the outcome and any other pertinent details describing the proposal's current status.

Current Funding, past funding available upon request

Project/Proposal Title: CoOP NE Pacific: The Role of Wind Driven Transport in Shelf Productivity Agency/Source of Support: National Science Foundation Award Amount: $ 946,349 Award Period Covered: 01/01/00 – 12/31/05 Location of Project: Davis, CA

Project/Proposal Title: US GLOBEC: Physical Influences on California Current Salmon Agency/Source of Support: National Science Foundation Award Amount: $ 597,000 Award Period Covered: 10/01/00 – 09/30/05 Location of Project: Davis, CA

All applicants must identify all sources of funding other than the funds requested through this solicitation to support the effort outlined in their proposal. Applicants must include the status of these commitments (tentative, approved, received), the source, and any cost−sharing requirements. Successful proposals that demonstrate multiple sources of funding must have the commitment of the non−Science Program PSP related funding within 30 days of notification of approval of Science Program PSP funds. If an applicant fails to secure the non−Science Program PSP funds identified in the proposal, and as a result has insufficient funds to complete the project, CBDA retains the option to amend or terminate the award. The California Bay−Delta Authority reserves the right to audit grantees.

Status	Proposal Title	Funding Source	Period Of Commitment	Requirements And Comments

Are you specifically seeking non−federal cost−share funds for this proposal?
No.

In addition to the general funds available, are you targeting additional funds set aside specifically for collaborative proposals?
No.

List people you feel are qualified to act as scientific reviewers for this proposal and are not associated with CALFED.

Full Name	Organization	Telephone	E−Mail	Expertise
John G. Williams		***530.753.7081***	***jgwill@dcn.davis.ca.us***	***fish biology, salmon and steelhead***
Carl Walters	***University of British Columbia***	***604.822.6320***	***c.walters@fisheries.ubc.ca***	***modeling, quantitative***
Jeremy S. Collie	***University of Rhode Island***	***401.874.6859***	***jcollie@gso.uri.edu***	***modeling, quantitative***

Executive Summary

Provide a brief but complete summary description of the proposed project; its geographic location; project objective; approach to implement the proposal; hypotheses being tested; expected outcomes; and relationship to Science Program priorities. The Executive Summary should be a concise, informative, stand−alone description of the proposed project. *(This information will be made public on our website shortly after the closing date of this PSP.)*

The project “A Statistical Model of Central Valley Chinook Incorporating Uncertainty” seeks to accomplish two general goals: 1. to formulate a modeling approach to threatened Central Valley chinook salmon runs, that accounts for mortality in all life stages, including the ocean, and that also accounts for both the variability in each stage, and the uncertainty in our understanding of each stage. The model will be used to develop an effective means of expressing population viability and a specific set of population criteria under which the Threatened and Endangered populations could be considered to be recovered. 2. to develop a methodology of decision making that will allow decision makers to achieve recovery goal s for the Central Valley salmon runs in a way that accounts for uncertainty, and also a parallel methodology that will suggest how decision makers can design data collection and designate research priorities on Central Valley salmonids in a way that reduces uncertainty most rapidly. The first goal will be accomplished through a Bayesian approach to fitting an age structured model that integrates elements of existing studies, simulation of a bioenergetic individual−based model, and retrospective analyses of ocean effects. The resulting model and expressions of associated uncertainty will be used to describe population jeopardy in a manner that accounts for uncertainty. The second goal will be accomplished through formal Bayesian decision analysis that accounts for both uncertainty in parameter values and the existence of multiple hypotheses regarding mechanisms underlying population dependence on environmental conditions. We will specifically assess the benefits to decision making of monitoring conditions in the local coastal ocean. These goals will be accomplished through a collaboration between UC Davis, R2 Resource Consultants and NOAA Fisheries scientists. UC Davis will supply expertise in Central Valley salmon, ocean influences and bioenergetic modeling, R2 will supply expertise in Bayesian estimation methods and the associated NOAA Fisheries scientists will supply expertise in endangered salmon.

Give additional comments, information, etc. here.

University of California, Davis has informed CalFed that they take exception with some clauses in the "Compliance with Standard Terms and Conditions" section of the PSP. The UC Davis details this in their "Letter of Support" for this grant. The letter may be viewed at: http://erizo.ucdavis.edu/~dmk/public/CalFed/UCD_LetterofSupport.pdf

Applicant

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All information on this page is to be provided for the agency or institution to whom funds for this proposal would be awarded.

Applicant Institution	***University of California, Davis***	*This list comes from the project form.*
Applicant Institution Type	***public institution of higher education***	

Institution Contact

Please provide information for the primary person responsible for oversight of grant operation, management, and reporting requirements.

Salutation	***Ms.***
First Name	***Rene***
Last Name	***Domino***
Street Address	***Office of Research***
City	***Davis***
State Or Province	***CA***
ZIP Code Or Mailing Code	***95616***
Telephone	***(530) 752−3754*** *Include area code.*
E−Mail	***rhdomino@ucdavis.edu***

Additional information regarding prior applications submitted to CALFED by the applicant organization or agency and/or funds received from CALFED programs by applicant organization or agency may be required.

Personnel

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Instructions

Applicants must provide brief biographical sketches, titles, affiliations, and descriptions of roles, relevant to this effort, of the principal and supporting project participants by completing a Personnel Form. This includes the use of any consultants, subcontractors and/or vendors; provide information on this form for all such people.

Information provided on this form will automatically support subsequent forms to be completed as part of the Science PSP submission process. Please be mindful of what information you enter and how it may be represented in the Task and Budget forms.

Information regarding anticipated subcontractor services must be provided regardless if the specific service provider has been selected or not. If the specific subcontractor has not been identified or selected, please list TBD (to be determined) in the Full Name field and the anticipated service type in the Title field (example: Hydrology Expert).

Please provide this information before continuing to those forms.

Botsford, Louis W., PhD.

*This person is the **Lead Investigator**. Contact information for this person is required.*

Full Name	***Botsford, Louis W., PhD.***	example: Wright, Jeffrey R., PhD.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Lead Principal Investigator; overall project management and task integration; design of models and of data analysis approaches	
Qualifications		*You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*
Mailing Address	***Dept of Wildlife, Fish and Conservation Biology; 1 Shields Ave.***	
City	***Davis***	
State	***CA***	
ZIP	***95616***	
Business Phone	***(530) 752−6169***	
Mobile Phone	***(530) 902−6644***	
E−Mail	***lwbotsford@ucdavis.edu***	

Describe other staff below. If you run out of spaces, submit your updates and return to this form.

Cech, Joseph J., PhD.

Full Name	***Cech, Joseph J., PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Professor***	*example: Dean of Engineering*

Position Classification	***primary staff***	
Responsibilities	Provide advice on which parts of the the bioenergetic model should be refocused and reparameterized to adequately model chinook salmon juveniles in the San Francisco ; design and implement laboratory experiments to measure key bioenergetic parameters for which no literature value is available.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Largier, John L., PhD.

Full Name	***Largier, John L., PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Associate Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Lead PI on local ocean monitoring, provide guidance on what monitored oceanographic parameters should be included in ocean models of Central Valley chinook salmon	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Lawrence, Cathryn A., PhD.

Full Name	***Lawrence, Cathryn A., PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Project Scientist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Develop bioenergetic model specific to juvenile chinook salmon in the Delta, implement model in spatially−explicit (linked to DSM2 via particle tracking) and spatially−implicit configurations; perform and assist in the design of ocean monitoring assessment; perform and assist in the design of assessment of ocean influences on Central Valley chinook salmon; contribute to Life Cycle, Leslie Matrix, and Bayesian Modeling efforts and to Decision Analysis and Web−based modeling Tasks	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Programmer

Full Name	***Programmer***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*

Title	***Programmer***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assist primary staff with programming tasks for modeling and data analysis, systems administration of workstation to be purchased for the project, configuration of workstation to host the Web−based interface to be developed in Task 9	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Undergraduate Student Assistant

Full Name	***Undergraduate Student Assistant***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Assistant II***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Under supervision of Cech, will measure bioenergetic parameters for the juvenile life−stages of Central Valley chinook salmon which are found in the estuary	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Administrative Assistant

Full Name	***Administrative Assistant***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Administrative Assistant II***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Provide secretarial assistance and word processing for production of reports, technical memos and peer−reviewed publications	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Hendrix, Noble, PhD.

Full Name	***Hendrix, Noble, PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***R2 Resource Consultants***	*This list comes from the project form.*
Title	***Biometrician; Senior Aquatic Ecologist***	*example: Dean of Engineering*
Position Classification	***subcontractor***	

Responsibilities	Facilitate life cycle model construction. Construct mathematical models from verbal hypotheses; fit population, survival, and statistical models to data; incorporate uncertainty into models; rank sources of uncertainty using statistical tools; perform Bayesian statistical data analyses; perform analysis of monitoring programs to reduce uncertainty; perform formal decision analysis.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Reiser, Dudley, PhD.

Full Name	***Reiser, Dudley, PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***R2 Resource Consultants***	*This list comes from the project form.*
Title	***Senior Fish Biologist***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Generate hypotheses and critique models, particularly instream flow effects on fish habitat and monitoring approaches to reduce uncertainty.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

DeVries, Paul, PhD. P.E.

Full Name	***DeVries, Paul, PhD. P.E.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***R2 Resource Consultants***	*This list comes from the project form.*
Title	***Senior Fish Biologist; Hydrologic Engineer***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Generate hypotheses and critique models, particularly instream flow effects on fish habitat and linking population models to hydrodynamic model output.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Loftus, Michael, PhD.

Full Name	***Loftus, Michael, PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***R2 Resource Consultants***	*This list comes from the project form.*
Title	***Senior Fish Biologist; Aquatic Toxicologist***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Generate hypotheses and critique models, particularly stressors associated with water quality; assist with decision analysis.	

Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Nightingale, Tim

Full Name	***Nightingale, Tim***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***R2 Resource Consultants***	*This list comes from the project form.*
Title	***Aquatic Ecologist***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Assist with data compilation, organization, and analysis.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Zablotney, Joetta,

Full Name	***Zablotney, Joetta,***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***R2 Resource Consultants***	*This list comes from the project form.*
Title	***GIS Coordinator***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Produce Geographic Information System (GIS) support for model output, particularly for web−based interactive model.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Huang, Chi−Ming, PhD., P.E.

Full Name	***Huang, Chi−Ming, PhD., P.E.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***R2 Resource Consultants***	*This list comes from the project form.*
Title	***Water Resources Engineer***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Assist in coding Leslie matrix model and hydrodynamic models; assist in coding web−based interactive model.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Greene, Correigh, PhD.

Full Name	***Greene, Correigh, PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***NOAA Fisheries***	*This list comes from the project form.*
Title	***Fish Biologist***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Provide expertise from Puget Sound stocks of chinook salmon; generate hypotheses and critique models, particularly life cycle model of chinook and Leslie matrix models; provide insight into density−dependent mechanisms.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Beechie, Tim, PhD.

Full Name	***Beechie, Tim, PhD.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***NOAA Fisheries***	*This list comes from the project form.*
Title	***Fish Biologist***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Provide ecosystem level perspective to salmon recovery; provide expertise from Puget Sound stocks of chinook salmon; generate hypotheses and critique models, particularly life cycle model of chinook and Leslie matrix models; provide insight into density−dependent mechanisms.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Conflict Of Interest

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Instructions

To help Science Program staff manage potential conflicts of interest in the review and selection process, we need some information about who will directly benefit if your proposal is funded. We need to know of individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded;
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.

Applicant	University of California, Davis
Submittor	Lawrence, Cathy
Primary Staff	Botsford, Louis W., PhD.
Primary Staff	Cech, Joseph J., PhD.
Primary Staff	Largier, John L., PhD.
Primary Staff	Lawrence, Cathryn A., PhD.
Secondary Staff	Programmer
Secondary Staff	Undergraduate Student Assistant
Secondary Staff	Administrative Assistant
Subcontractor	Hendrix, Noble, PhD.
Subcontractor	Reiser, Dudley, PhD.
Subcontractor	DeVries, Paul, PhD. P.E.
Subcontractor	Loftus, Michael, PhD.
Subcontractor	Nightingale, Tim
Subcontractor	Zablotney, Joetta,
Subcontractor	Huang, Chi−Ming, PhD., P.E.
Subcontractor	Greene, Correigh, PhD.
Subcontractor	Beechie, Tim, PhD.

Are there other persons not listed above who helped with proposal development?
No.

If there are, provide below the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

Tasks

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Instructions

Utilize this Task Table to delineate the tasks identified in your project description. Each task and subtask must have a number, title, brief description of the task (detailed information should be provided in the project description), timeline, list of personnel or subcontractors providing services on each specific task, and list of anticipated deliverables (where appropriate). When creating subtasks, information must be provided in a way that avoids duel presentation of supporting tasks within the overall task (i.e. avoid double counting). Information provided in the Task Table will be used to support the Budget Form. Ensuring information regarding deliverables, personnel and costs associated with subtasks are only provided once is imperative for purposes of avoiding double counting of efforts within the Budget Form.

For proposals involving multiple institutions (including subcontractors), the table must clearly state which institutions are performing which tasks and subtasks.

Task ID	Task Name	Start Month	End Month	Personnel Involved	Description	Deliverables
1.1	***Develop life cycle models***	*1*	*12*	***Botsford, Louis W., PhD. Lawrence, Cathryn A., PhD. Hendrix, Noble, PhD. Reiser, Dudley, PhD. DeVries, Paul, PhD. P.E. Loftus, Michael, PhD. Greene, Correigh, PhD. Beechie, Tim, PhD.***	Develop conceptual life cycle models of winter−run and spring−run Chinook, generate hypotheses about factors affecting life history stage vital rates	Winter−run conceptual model memo, Spring−run conceptual model memo R2: identify and critique conceptual models, facilitate construction of conceptual models
1.2	***Develop Bayesian model−fitting framework***	*1*	*12*	***Hendrix, Noble, PhD.***	Identify and obtain available data for model fitting, develop a statistical framework for using available data to estimate life history stage vital rates and for fitting Leslie matrix model to escapement data	Memo describing the Bayesian modeling framework and data available for model fitting, test of simplified modeling framework with simulated data
2.1	***Leslie Matrix Models: Convert multiple working hypotheses into mathematical models***	*1*	*18*	***Botsford, Louis W., PhD. Hendrix, Noble, PhD. Greene, Correigh, PhD. Beechie, Tim, PhD.***	Construct Leslie matrix models with parameter and structural uncertainty, convert multiple working hypotheses into mathematical models, fit models to escapement data	Memo of the Leslie matrix models for winter and spring−run chinook, Model code of working Leslie matrix models
2.2	***Leslie Matrix Models: Perform PVA with uncertainty***	*1*	*18*	***Botsford, Louis W., PhD. Hendrix, Noble, PhD.***	Perform Population Viability Analysis (PVA) with uncertainty, identify delisting criteria, evaluate recovery of runs	Technical Memorandum of PVA with uncertainty, delisting criteria, and recovery options
3	***Statistical Analysis***					

		4	*24*	***Botsford, Louis W., PhD.*** ***Hendrix, Noble, PhD.*** ***Nightingale, Tim***	Perform Bayesian analysis of stage or habitat specific data, evaluate applicability of juvenile survival studies in Sacramento River and Delta to winter and spring−run chinook	Statistical analysis memorandum, results of Bayesian analysis of stage or habitat specific data, evaluation of juvenile survival studies in Sacramento River and Delta
4.1	***Ocean Monitoring Assessment***	*1*	*36*	***Botsford, Louis W., PhD.*** ***Largier, John L., PhD.*** ***Lawrence, Cathryn A., PhD.*** ***Programmer***	Analyze local oceanographic data for Gulf of the Farallons with fall−, spring− and winter−run salmon returns to determine whether local oceanographic effects add predictive ability beyond using coast−wide California Current System data for prediction	Technical memo covering Task 4.1−4.3 describing outcome of ocean monitoring assessment, retrospective data analysis and model fitting
4.2	***Retrospective data analysis of ocean effects on Central Valley chinook salmon***	*1*	*24*	***Botsford, Louis W., PhD.*** ***Largier, John L., PhD.*** ***Lawrence, Cathryn A., PhD.*** ***Programmer***	Exploratory retrospective data analysis to determine which indicators of oceanographic conditions in the California Current System have predictive ability relative to returns of fall−, spring− and winter−run chinook salmon	Technical memo covering Task 4.1−4.3 describing outcome of ocean monitoring assessment, retrospective data analysis and model fitting
4.3	***Fitting of ocean effects model to escapement and other data***	*12*	*24*	***Botsford, Louis W., PhD.*** ***Lawrence, Cathryn A., PhD.*** ***Programmer*** ***Hendrix, Noble, PhD.***	Fit nonlinear Leslie matrix model of chinook salmon to time−series of ocean indicators determined in Task 4.2	Technical memo covering Task 4.1−4.3 describing outcome of ocean monitoring assessment, retrospective data analysis and model fitting
5.1	***Evaluation of bioenergetic individual−based modeling strategies***	*4*	*10*	***Botsford, Louis W., PhD.*** ***Largier, John L., PhD.*** ***Lawrence, Cathryn A., PhD.*** ***Programmer***	Assessment of spatially−explicit (using particle tracking in DSM2) and spatially−implicit configurations of bioenergetic model; choice effort allocation to each modeling strategy; design of simulation scenarios	Memo to be circulated within the CALFED research and management community to solicit feedback on our planned bioenergetic modeling
5.2	***Refinement of bioenergetic individual−based model including lab measurements of bioenergetic parameters***	*6*	*25*	***Cech, Joseph J., PhD.*** ***Lawrence, Cathryn A., PhD.*** ***Undergraduate Student Assistant***	Bioenergetic IBM re−parameterization and refinement including lab measurement of parameters	Technical memo describing bioenergetic IBM including details about re−parameterizaton Technical memo describing bioenergetic IBM including details about re−parameterizaton
5.3	***Conduct Bioenergetic Model runs***	*4*	*27*	***Lawrence, Cathryn A., PhD.*** ***Programmer*** ***Hendrix, Noble, PhD.***	Conduct modeling studies with strategies identified in Task 5.1 with model from Task 5.2; provide output of these models to ocean and Bayesian models.	Technical memo describing results of spatially−explicit and spatially−implicit bioenergetic modeling.
6	***Model Refinement***	*12*	*27*	***Botsford, Louis W., PhD.*** ***Largier, John L., PhD.*** ***Lawrence,***	Update model to reflect Statistical Analysis (Task 3), uncertainty in survival from the Ocean model (Task 4), and uncertainty in Delta survival from Bioenergetics model (Task 5) into the Leslie matrix model, integrate comments from CBDA	Memo describing the linkages to the bioenergetics, ocean model, and statistical data analysis tasks

				Cathryn A., PhD. Programmer Hendrix, Noble, PhD. Reiser, Dudley, PhD. DeVries, Paul, PhD. P.E. Loftus, Michael, PhD. Huang, Chi−Ming, PhD., P.E. Greene, Correigh, PhD. Beechie, Tim, PhD.		
7	***Improve Monitoring***	***24***	***36***	***Botsford, Louis W., PhD. Largier, John L., PhD. Lawrence, Cathryn A., PhD. Programmer Hendrix, Noble, PhD. Reiser, Dudley, PhD. DeVries, Paul, PhD. P.E. Greene, Correigh, PhD. Beechie, Tim, PhD.***	Simulate sampling designs to evaluate reduction in uncertainty from improved/additional monitoring	Technical memorandum describing the reduction in uncertainty from improved/additional monitoring
8	***Decision Analysis***	***24***	***36***	***Botsford, Louis W., PhD. Lawrence, Cathryn A., PhD. Programmer Hendrix, Noble, PhD. Reiser, Dudley, PhD. DeVries, Paul, PhD. P.E. Loftus, Michael, PhD. Greene, Correigh, PhD. Beechie, Tim, PhD.***	Conduct a formal decision analysis of management actions in light of parameter and structural uncertainty in the Leslie matrix model	Technical memorandum of decision analysis of selected recovery actions
9	***Web−based Model Development***	***18***	***36***	***Botsford, Louis W., PhD. Lawrence, Cathryn A., PhD. Programmer Hendrix, Noble,***	Develop and maintain project website at UC Davis to be the hub for dissemination of project results from all Tasks, in addition to result content from each of the Tasks, all semiannual reports and other deliverables will be available through the website	Web page that provides the functionality described, model code to run deterministic Leslie matrix model in web−based framework

				PhD. Zablotney, Joetta, Greene, Correigh, PhD. Beechie, Tim, PhD.		
10	***Attend Technical Meetings***	***1***	***36***	***Botsford, Louis W., PhD. Cech, Joseph J., PhD. Largier, John L., PhD. Lawrence, Cathryn A., PhD. Hendrix, Noble, PhD. Reiser, Dudley, PhD. Greene, Correigh, PhD. Beechie, Tim, PhD.***	Two meetings annually to discuss model development, integration, and data analysis, plus one floating meetings as the project needs. The first meeting will be to discuss the Life Cycle model and generate hypotheses about factors affecting life history stage vital rates; attend biennial CalFed Science Conferences; attend annual IEP Workshops	Meeting agendas for summaries of each internal meeting; presentations at CALFED biennial Science Conferences including abstracts to be available on our website; presentations at annual IEP Workshop including abstracts to be available on our website
11	***Report Preparation and Project Management***	***1***	***36***	***Botsford, Louis W., PhD. Cech, Joseph J., PhD. Largier, John L., PhD. Lawrence, Cathryn A., PhD. Administrative Assistant Hendrix, Noble, PhD. Reiser, Dudley, PhD. DeVries, Paul, PhD. P.E. Loftus, Michael, PhD. Nightingale, Tim Zablotney, Joetta, Huang, Chi−Ming, PhD., P.E. Greene, Correigh, PhD. Beechie, Tim, PhD.***	Prepare semiannual reports for CBDA, correspond with CBDA and respond to comments	Semiannual progress reports to CBDA, final report to CBDA

Budget

This proposal is for the Science Program 2004 solicitation as prepared by Lawrence, Cathy .

The submission deadline is 2005−01−06 17:00:00 PST (approximately 13 minutes from now).

Proposal updates will be disabled immediately after the deadline. All forms, including the signature form, must be completed, compiled and acknowledged in order to be eligible for consideration and review. Allow at least one hour for Science Program staff to verify and file signature pages after they are received.

Instructions

All applicants must complete a budget for each task and subtask. The Budget Form uses data entered in the Task Form, thus tasks should be entered before starting this form. Failure to complete a Budget Form for each task and/or subtask will result in removal of the application from consideration for funding.

CBDA retains the right to request additional information pertaining to the items, rates, and justification of the information presented in the Budget Form(s).

Supporting details on how costs were derived for each line item must be included in the justification section for each item. The cost detail for each item should include the individual cost calculations associated with each line item to provide the basis for determining the total amount for each budget category.

Following are guidelines for completing the justification section of this form:

Labor (Salary &Wages)
: Ensure each employee and associated classification is correctly identified for each task and subtask. This information will automatically be provided once the Staff Form has been completed. Provide estimated hours and hourly rate of compensation for each position proposed in the project.

Employee Benefits
: Benefits, calculated as a percentage of salaries, are contributions made by the applicant for sick leave, retirement, insurance, etc. Provide the overall benefit rate and specify benefits included in this rate for each employee classification proposed in the project.

Travel
: Travel includes the cost of transportation, subsistence, and other associated costs incurred by personnel during the term of the project. Provide purpose and estimated costs for all travel. Reoccurring travel costs for a particular task or subtask may be combined into one entry. The number of trips and cost for each occurrence must be clearly represented in the justification section for reoccurring travel items of this nature.

  Any reimbursement for necessary travel and per diem shall be at rates specified by the California Department of Personnel Administration for similar employees (www.dpa.ca.gov/jobinfo/statetravel.shtm).

Equipment
: Equipment is classified as any item of $5,000 or more and has an expected life of three years or more. Equipment purchased in whole or in part with these grant funds must be itemized. List each piece of equipment and provide a brief description and justification for each.

Supplies
: Provide a basic description and cost for expendable research supplies. Costs associated with GIS services, air photos, reports, etc. must be listed separately and have a clear justification associated with each entry. Postage, copying, phone, fax and other basic operational costs associated with each task and subtask may be combined unless the cost associated with one particular service is unusually excessive.

Subcontractor Services
: Subcontractor services (Professional and Consultant services) include the total costs for any services needed by the applicant to complete the project tasks. Ensure the correct organization is entered in the Personnel Form so that it appropriately appears on the Budget Form. The applicant must provide all associated costs of all subcontractors (i.e. outside service providers) when completing this form. Applicants must be able to demonstrate that all subcontractors were selected according to an applicant's institutional requirements for the selection of subcontractors (competitive selection or sole source justification).

  CBDA retains the right to request that a subcontractor provide cost estimates in writing prior to distribution of grant funds.

  CBDA retains the right to request consultant, subcontractor, and/or outside service provider cost estimates in writing prior to distribution of grant funds.

Indirect Costs (Overhead)
: Indirect costs are overhead expenses incurred by the applicant organization as a result of the project but are not easily identifiable with a specific project. The indirect cost rate consists of a reasonable percentage of all costs to run the agency or organization while completing the project. List the cost and items associated with indirect costs. (These items may include general office expenses such as rent, office equipment, administrative staff, operational costs, etc. Generally these items are represented by the applicant through a predetermined percentage or surcharge separate from other specific costs of items necessary to complete a specific task or subtask.)

If indirect cost rates are different for State and Federal funds, please identify each rate and the specific items included in the calculation for that rate.

Task 1.1, Develop Life Cycle Models: Labor	Justification	Amount
Botsford, Louis W., PhD.	*0.5 months, salary paid by UCD*	*0*
Lawrence, Cathryn A., PhD.	*3 months salary*	*12725*
Task 1.1, Develop Life Cycle Models: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	*benefits paid by UCD*	*0*
Lawrence, Cathryn A., PhD.	*17% of salary*	*2163*
Task 1.1, Develop Life Cycle Models: Travel Expenses	**Justification**	**Amount**
Task 1.1, Develop Life Cycle Models: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	*General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task*	*534*
Task 1.1, Develop Life Cycle Models: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	*160hrs X $87 + $2675 ODC*	*16595*
Reiser, Dudley, PhD.	*16hrs X $167*	*2672*
DeVries, Paul, PhD. P.E.	*16hrs X $127*	*2032*
Loftus, Michael, PhD.	*16hrs X $144*	*2304*
Greene, Correigh, PhD.	*40hrs X $84*	*3360*
Beechie, Tim, PhD.	*40hrs X 100*	*4000*
Task 1.1, Develop Life Cycle Models: Equipment	**Justification**	**Amount**
Task 1.1, Develop Life Cycle Models: Other Direct	**Justification**	**Amount**
Task 1.1, Develop Life Cycle Models: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*5372*
	Task 1.1 Total	$51,757
Task 1.2, Develop Bayesian Model−Fitting Framework: Labor	**Justification**	**Amount**
No staff was assigned to this task.		
Task 1.2, Develop Bayesian Model−Fitting Framework: Benefits	**Justification**	**Amount**
No staff was assigned to this task.		
Task 1.2, Develop Bayesian Model−Fitting Framework: Travel Expenses	**Justification**	**Amount**
Task 1.2, Develop Bayesian Model−Fitting Framework: Supplies And Expendables	**Justification**	**Amount**
Task 1.2, Develop Bayesian Model−Fitting Framework: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	*160hrs X $87 + $2,591 ODC including 50% of computer purchase*	*16511*
Task 1.2, Develop Bayesian Model−Fitting Framework: Equipment	**Justification**	**Amount**
Task 1.2, Develop Bayesian Model−Fitting Framework: Other Direct	**Justification**	**Amount**
Task 1.2, Develop Bayesian Model−Fitting Framework: Indirect (Overhead)	**Justification**	**Amount**

	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*323*
	Task 1.2 Total	$16,834
Task 2.1, Leslie Matrix Models: Convert Multiple Working Hypotheses Into Mathematical Models: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*0.15 months, salary paid by UCD*	*0*
Task 2.1, Leslie Matrix Models: Convert Multiple Working Hypotheses Into Mathematical Models: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	*benefits paid by UCD*	
Task 2.1, Leslie Matrix Models: Convert Multiple Working Hypotheses Into Mathematical Models: Travel Expenses	**Justification**	**Amount**
Task 2.1, Leslie Matrix Models: Convert Multiple Working Hypotheses Into Mathematical Models: Supplies And Expendables	**Justification**	**Amount**
Task 2.1, Leslie Matrix Models: Convert Multiple Working Hypotheses Into Mathematical Models: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	*320hrs X $87 + $3, 819 ODC, including 50% of computer purchase*	*31659*
Greene, Correigh, PhD.	*40hrs X $84*	*3360*
Beechie, Tim, PhD.	*40hrs X 100*	*4000*
Task 2.1, Leslie Matrix Models: Convert Multiple Working Hypotheses Into Mathematical Models: Equipment	**Justification**	**Amount**
Task 2.1, Leslie Matrix Models: Convert Multiple Working Hypotheses Into Mathematical Models: Other Direct	**Justification**	**Amount**
Task 2.1, Leslie Matrix Models: Convert Multiple Working Hypotheses Into Mathematical Models: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*1674*
	Task 2.1 Total	$40,693
Task 2.2, Leslie Matrix Models: Perform PVA With Uncertainty: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*0.15 months, salary paid by UCD*	*0*
Task 2.2, Leslie Matrix Models: Perform PVA With Uncertainty: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	*benefits paid by UCD*	*0*
Task 2.2, Leslie Matrix Models: Perform PVA With Uncertainty: Travel Expenses	**Justification**	**Amount**
Task 2.2, Leslie Matrix Models: Perform PVA With Uncertainty: Supplies And Expendables	**Justification**	**Amount**
Task 2.2, Leslie Matrix Models: Perform PVA With Uncertainty: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	*320hrs X $87 + $216 ODC*	*28056*
Task 2.2, Leslie Matrix Models: Perform PVA With Uncertainty: Equipment	**Justification**	**Amount**

Task 2.2, Leslie Matrix Models: Perform PVA With Uncertainty: Other Direct	Justification	Amount
Task 2.2, Leslie Matrix Models: Perform PVA With Uncertainty: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*549*
	Task 2.2 Total	$28,605
Task 3, Statistical Analysis: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*0.3 months, salary paid by UCD*	*0*
Task 3, Statistical Analysis: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	*benefits paid by UCD*	
Task 3, Statistical Analysis: Travel Expenses	**Justification**	**Amount**
Task 3, Statistical Analysis: Supplies And Expendables	**Justification**	**Amount**
Task 3, Statistical Analysis: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	*240hrs X $87 + $4201.50 ODC, including 3 trips to Sacramento for data aquisition*	*25119*
Nightingale, Tim	*120hrs X $66*	*7920*
Task 3, Statistical Analysis: Equipment	**Justification**	**Amount**
Task 3, Statistical Analysis: Other Direct	**Justification**	**Amount**
Task 3, Statistical Analysis: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*647*
	Task 3 Total	$33,686
Task 4.1, Ocean Monitoring Assessment: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*1.5 months, salary paid by UCD*	*0*
Largier, John L., PhD.	*1.8 months salary*	*17558*
Lawrence, Cathryn A., PhD.	*3 months salary*	*13111*
Programmer	*.6 months salary*	*2802*
Task 4.1, Ocean Monitoring Assessment: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	*benefits paid by UCD*	*0*
Largier, John L., PhD.	*17% of salary*	*2985*
Lawrence, Cathryn A., PhD.	*17% of salary*	*2229*
Programmer	*22% of salary*	*617*
Task 4.1, Ocean Monitoring Assessment: Travel Expenses	**Justification**	**Amount**
Task 4.1, Ocean Monitoring Assessment: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	*General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task*	*1404*
Task 4.1, Ocean Monitoring Assessment: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 4.1, Ocean Monitoring Assessment: Equipment	**Justification**	**Amount**
Computer Workstation/Fileserver	*20% of cost of high end computer workstation with RAID and tape backup; to*	*1000*

	be used for modeling, analysis and data hosting in first two years of project but will become the machine that hosts the Web−based model Interface developed in Year 3 (Task 9)	
Task 4.1, Ocean Monitoring Assessment: Other Direct	**Justification**	**Amount**
Task 4.1, Ocean Monitoring Assessment: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*10176*
	Task 4.1 Total	$51,882
Task 4.2, Retrospective Data Analysis Of Ocean Effects On Central Valley Chinook Salmon: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*1.3 months, salary paid by UCD*	*0*
Largier, John L., PhD.	*0.4 months salary*	*3844*
Lawrence, Cathryn A., PhD.	*7 months salary*	*30332*
Programmer	*.8 months salary*	*3695*
Task 4.2, Retrospective Data Analysis Of Ocean Effects On Central Valley Chinook Salmon: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	*benefits paid by UCD*	*0*
Largier, John L., PhD.	*17% of salary*	*653*
Lawrence, Cathryn A., PhD.	*17% of salary*	*5156*
Programmer	*22% of salary*	*813*
Task 4.2, Retrospective Data Analysis Of Ocean Effects On Central Valley Chinook Salmon: Travel Expenses	**Justification**	**Amount**
Task 4.2, Retrospective Data Analysis Of Ocean Effects On Central Valley Chinook Salmon: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	*General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task*	*1588*
Task 4.2, Retrospective Data Analysis Of Ocean Effects On Central Valley Chinook Salmon: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 4.2, Retrospective Data Analysis Of Ocean Effects On Central Valley Chinook Salmon: Equipment	**Justification**	**Amount**
Computer Workstation/Fileserver	*20% of cost of high end computer workstation with RAID and tape backup; to be used for modeling, analysis and data hosting in first two years of project but will become the machine that hosts the Web−based model Interface developed in Year 3 (Task 9_*	*1000*
Task 4.2, Retrospective Data Analysis Of Ocean Effects On Central Valley Chinook Salmon: Other Direct	**Justification**	**Amount**
Task 4.2, Retrospective Data Analysis Of Ocean Effects On Central Valley Chinook Salmon: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*11520*
	Task 4.2 Total	$58,601
Task 4.3, Fitting Of Ocean Effects Model To Escapement And Other Data: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*1.3 months, salary paid by UCD*	*0*

Lawrence, Cathryn A., PhD.	***3 months salary***	***13369***
Programmer	***1.1 months salary***	***5068***
Task 4.3, Fitting Of Ocean Effects Model To Escapement And Other Data: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	***benefits paid by UCD***	***0***
Lawrence, Cathryn A., PhD.	***17% of salary***	***2273***
Programmer	***22% of salary***	***1115***
Task 4.3, Fitting Of Ocean Effects Model To Escapement And Other Data: Travel Expenses	**Justification**	**Amount**
Task 4.3, Fitting Of Ocean Effects Model To Escapement And Other Data: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	***General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task***	***773***
Task 4.3, Fitting Of Ocean Effects Model To Escapement And Other Data: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	***100hrs X $87 + $523 ODC***	***9223***
Task 4.3, Fitting Of Ocean Effects Model To Escapement And Other Data: Equipment	**Justification**	**Amount**
Computer Workstation/Fileserver	***20% of cost of high end computer workstation with RAID and tape backup; to be used for modeling, analysis and data hosting in first two years of project but will become the machine that hosts the Web−based model Interface developed in Year 3 (Task 9_***	***1000***
Task 4.3, Fitting Of Ocean Effects Model To Escapement And Other Data: Other Direct	**Justification**	**Amount**
Task 4.3, Fitting Of Ocean Effects Model To Escapement And Other Data: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	***5830***
	Task 4.3 Total	$38,651
Task 5.1, Evaluation Of Bioenergetic Individual−Based Modeling Strategies: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	***0.5 months, salary paid by UCD***	***0***
Largier, John L., PhD.	***0.05 months salary***	***473***
Lawrence, Cathryn A., PhD.	***1.5 months salary***	***6363***
Programmer	***0.5 months salary***	***2267***
Task 5.1, Evaluation Of Bioenergetic Individual−Based Modeling Strategies: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	***benefits paid by UCD***	***0***
Largier, John L., PhD.	***17% of salary***	***80***
Lawrence, Cathryn A., PhD.	***17% of salary***	***1082***
Programmer	***22% of salary***	***499***
Task 5.1, Evaluation Of Bioenergetic Individual−Based Modeling Strategies: Travel Expenses	**Justification**	**Amount**
Task 5.1, Evaluation Of Bioenergetic Individual−Based Modeling Strategies: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	***General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task***	***382***

Task 5.1, Evaluation Of Bioenergetic Individual−Based Modeling Strategies: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 5.1, Evaluation Of Bioenergetic Individual−Based Modeling Strategies: Equipment	**Justification**	**Amount**
Computer Workstation/Fileserver	***10% of cost of high end computer workstation with RAID and tape backup; to be used for modeling, analysis and data hosting in first two years of project but will become the machine that hosts the Web−based model Interface developed in Year 3 (Task 9_***	***500***
Task 5.1, Evaluation Of Bioenergetic Individual−Based Modeling Strategies: Other Direct	**Justification**	**Amount**
Task 5.1, Evaluation Of Bioenergetic Individual−Based Modeling Strategies: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	***2786***
	Task 5.1 Total	$14,432
Task 5.2, Refinement Of Bioenergetic Individual−Based Model Including Lab Measurements Of Bioenergetic Parameters: Labor	**Justification**	**Amount**
Cech, Joseph J., PhD.	***.9 month, salary paid by UCD***	***0***
Lawrence, Cathryn A., PhD.	***2.6 months salary***	***11206***
Undergraduate Student Assistant	***9 months (2 summers full−time)***	***7308***
Task 5.2, Refinement Of Bioenergetic Individual−Based Model Including Lab Measurements Of Bioenergetic Parameters: Benefits	**Justification**	**Amount**
Cech, Joseph J., PhD.	***benefits paid by UCD***	***0***
Lawrence, Cathryn A., PhD.	***17% of salary***	***1905***
Undergraduate Student Assistant	***3% of salary***	***219***
Task 5.2, Refinement Of Bioenergetic Individual−Based Model Including Lab Measurements Of Bioenergetic Parameters: Travel Expenses	**Justification**	**Amount**
Task 5.2, Refinement Of Bioenergetic Individual−Based Model Including Lab Measurements Of Bioenergetic Parameters: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	***General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task***	***470***
Other	***Wet lab supplies to be used for measuring bioenergetic parameter in Cech's lab***	***6000***
Task 5.2, Refinement Of Bioenergetic Individual−Based Model Including Lab Measurements Of Bioenergetic Parameters: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 5.2, Refinement Of Bioenergetic Individual−Based Model Including Lab Measurements Of Bioenergetic Parameters: Equipment	**Justification**	**Amount**
Task 5.2, Refinement Of Bioenergetic Individual−Based Model Including Lab Measurements Of Bioenergetic Parameters: Other Direct	**Justification**	**Amount**
Task 5.2, Refinement Of Bioenergetic Individual−Based Model Including Lab Measurements Of Bioenergetic Parameters: Indirect (Overhead)	**Justification**	**Amount**

	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*6777*
	Task 5.2 Total	$33,885
Task 5.3, Conduct Bioenergetic Model Runs: Labor	**Justification**	**Amount**
Lawrence, Cathryn A., PhD.	*4.7 months salary*	*20447*
Programmer	*1.05 months salary*	*4842*
Task 5.3, Conduct Bioenergetic Model Runs: Benefits	**Justification**	**Amount**
Lawrence, Cathryn A., PhD.	*17% of salary*	*3476*
Programmer	*22% of salary*	*1065*
Task 5.3, Conduct Bioenergetic Model Runs: Travel Expenses	**Justification**	**Amount**
Task 5.3, Conduct Bioenergetic Model Runs: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	*General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task*	*1060*
Task 5.3, Conduct Bioenergetic Model Runs: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	*40hrs X $87 + $92 ODC*	*3572*
Task 5.3, Conduct Bioenergetic Model Runs: Equipment	**Justification**	**Amount**
Computer Workstation/Fileserver	*20% of cost of high end computer workstation with RAID and tape backup; to be used for modeling, analysis and data hosting in first two years of project but will become the machine that hosts the Web−based model Interface developed in Year 3 (Task 9_*	*1000*
Task 5.3, Conduct Bioenergetic Model Runs: Other Direct	**Justification**	**Amount**
Task 5.3, Conduct Bioenergetic Model Runs: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*7792*
	Task 5.3 Total	$43,254
Task 6, Model Refinement: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*0.6 months, salary paid by UCD*	*0*
Largier, John L., PhD.	*0.05 month salary*	*488*
Lawrence, Cathryn A., PhD.	*1 month salary*	*4369*
Programmer	*0.2 months salary*	*934*
Task 6, Model Refinement: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	*benefits paid by UCD*	*0*
Largier, John L., PhD.	*17% of salary*	*83*
Lawrence, Cathryn A., PhD.	*17% of salary*	*743*
Programmer	*22% of salary*	*205*
Task 6, Model Refinement: Travel Expenses	**Justification**	**Amount**
Task 6, Model Refinement: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	*General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task*	*243*
Task 6, Model Refinement: Subcontractors	**Justification**	**Amount**

Hendrix, Noble, PhD.	***240hrs X $87 + $1512 ODC***	***22392***
Reiser, Dudley, PhD.	***8hrs X $167***	***1336***
DeVries, Paul, PhD. P.E.	***8hrs X $127***	***1016***
Loftus, Michael, PhD.	***8hrs X $144***	***1152***
Huang, Chi−Ming, PhD., P.E.	***120hrs X $92***	***11040***
Greene, Correigh, PhD.	***20hrs X $84***	***1680***
Beechie, Tim, PhD.	***20hrs X 100***	***2000***
Task 6, Model Refinement: Equipment	**Justification**	**Amount**
Computer Workstation/Fileserver	***10% of cost of high end computer workstation with RAID and tape backup; to be used for modeling, analysis and data hosting in first two years of project but will become the machine that hosts the Web−based model Interface developed in Year 3 (Task 9_***	***500***
Task 6, Model Refinement: Other Direct	**Justification**	**Amount**
Task 6, Model Refinement: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	***3016***
	Task 6 Total	$51,197
Task 7, Improve Monitoring: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	***0.6 months, salary paid by UCD***	***0***
Largier, John L., PhD.	***0.2 months salary***	***2009***
Lawrence, Cathryn A., PhD.	***2.2 months salary***	***9900***
Programmer	***0.25 months salary***	***1202***
Task 7, Improve Monitoring: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	***benefits paid by UCD***	***0***
Largier, John L., PhD.	***17% of salary***	***342***
Lawrence, Cathryn A., PhD.	***17% of salary***	***1683***
Programmer	***22% of salary***	***265***
Task 7, Improve Monitoring: Travel Expenses	**Justification**	**Amount**
Task 7, Improve Monitoring: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	***General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task***	***550***
Task 7, Improve Monitoring: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	***160hrs X $87 + $1,507 ODC***	***15427***
Reiser, Dudley, PhD.	***8hrs X $167***	***1336***
DeVries, Paul, PhD. P.E.	***8hrs X $127***	***1016***
Greene, Correigh, PhD.	***20hrs X $84***	***1680***
Beechie, Tim, PhD.	***20hrs X 100***	***2000***
Task 7, Improve Monitoring: Equipment	**Justification**	**Amount**
Task 7, Improve Monitoring: Other Direct	**Justification**	**Amount**
Task 7, Improve Monitoring: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	***4863***
	Task 7 Total	$42,273
Task 8, Decision Analysis: Labor	**Justification**	**Amount**

Botsford, Louis W., PhD.	***0.7 months, salary paid by UCD***	***0***
Lawrence, Cathryn A., PhD.	***2.2 months salary***	***9900***
Programmer	***0.25 months salary1202***	***1202***
Task 8, Decision Analysis: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	***benefits paid by UCD***	***0***
Lawrence, Cathryn A., PhD.	***17% of salary***	***1683***
Programmer	***22% of salary***	***265***
Task 8, Decision Analysis: Travel Expenses	**Justification**	**Amount**
Task 8, Decision Analysis: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	***General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task***	***466***
Task 8, Decision Analysis: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	***160hrs X $87 + $ 2,902 ODC***	***16822***
Reiser, Dudley, PhD.	***8hrs X $167***	***1336***
DeVries, Paul, PhD. P.E.	***8hrs X $127***	***1016***
Loftus, Michael, PhD.	***40hrs X $144***	***5760***
Greene, Correigh, PhD.	***20hrs X $84***	***1680***
Beechie, Tim, PhD.	***20hrs X 100***	***2000***
Task 8, Decision Analysis: Equipment	**Justification**	**Amount**
Task 8, Decision Analysis: Other Direct	**Justification**	**Amount**
Task 8, Decision Analysis: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	***4394***
	Task 8 Total	$46,524
Task 9, Web−Based Model Development: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	***0.1 months, salary paid by UCD***	***0***
Lawrence, Cathryn A., PhD.	***1.5 months salary***	***6684***
Programmer	***1.25 months salary***	***6012***
Task 9, Web−Based Model Development: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	***benefits paid by UCD***	***0***
Lawrence, Cathryn A., PhD.	***17% of salary***	***1136***
Programmer	***22% of salary***	***1323***
Task 9, Web−Based Model Development: Travel Expenses	**Justification**	**Amount**
Task 9, Web−Based Model Development: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	***General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task***	***532***
Task 9, Web−Based Model Development: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	***120hrs X $87 + $1,512 ODC***	***11952***
Zablotney, Joetta,	***120hrs X $101 + $1,600 GIS operations***	***13720***
Greene, Correigh, PhD.	***10hrs X $84***	***840***
Beechie, Tim, PhD.	***10hrs X 100***	***1000***
Task 9, Web−Based Model Development: Equipment	**Justification**	**Amount**

Task 9, Web−Based Model Development: Other Direct	**Justification**	**Amount**
Task 9, Web−Based Model Development: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*4688*
	Task 9 Total	$47,887
Task 10, Attend Technical Meetings: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*.3 months, salary paid by UCD*	*0*
Cech, Joseph J., PhD.	*.15 months salary, salary paid by UCD*	*0*
Largier, John L., PhD.	*.15 months salary*	*1463*
Lawrence, Cathryn A., PhD.	*.3 months*	*1311*
Task 10, Attend Technical Meetings: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	*benefits paid by UCD*	*0*
Cech, Joseph J., PhD.	*benefits paid by UCD*	*0*
Largier, John L., PhD.	*17% of salary*	*249*
Lawrence, Cathryn A., PhD.	*17% of salary*	*223*
Task 10, Attend Technical Meetings: Travel Expenses	**Justification**	**Amount**
Conferences	*Cost of Botsford, Lawrence and Largier to attend biennial CalFed Science Conferences in 2006 and 2008 at $300 per investigator per meeting; assumes Sacramento venue*	*1800*
Conferences	*Cost of Botsford, Lawrence and Largier to attend annual IEP Workshop each year; assumes $450 per investigator per meeting; assumes Asilomar venue*	*4050*
Conferences	*Travel to Seattle, WA 2 person trips per year for technical meetings with R2 and NMFS investigators*	*3150*
Task 10, Attend Technical Meetings: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	*General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task*	*116*
Task 10, Attend Technical Meetings: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	*144hrs X $87 + $ 14,310 ODC (includes airfare, lodging, transportation for R2 personnel−2 CALFED meetings, 2 tech meetings per year, 1 floating)*	*29398*
Reiser, Dudley, PhD.	*24hrs X $167*	*4008*
Greene, Correigh, PhD.	*40hrs X $84 + 1 trip to Sacramento*	*4010*
Beechie, Tim, PhD.	*40hrs X 100 + 1 trip to Sacramento*	*4650*
Task 10, Attend Technical Meetings: Equipment	**Justification**	**Amount**
Task 10, Attend Technical Meetings: Other Direct	**Justification**	**Amount**
Task 10, Attend Technical Meetings: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	*4985*
	Task 10 Total	$59,413
Task 11, Report Preparation And Project Management: Labor	**Justification**	**Amount**
Botsford, Louis W., PhD.	*1 month, salary paid by UCD*	*0*
Cech, Joseph J., PhD.	*.2 month, salary paid by UCD*	*0*
Largier, John L., PhD.	*.35 months salary*	*3429*

Lawrence, Cathryn A., PhD.	***4 months Salary***	***17611***
Administrative Assistant	***2.25 months salary***	***6840***
Task 11, Report Preparation And Project Management: Benefits	**Justification**	**Amount**
Botsford, Louis W., PhD.	***benefits paid by UCD***	***0***
Cech, Joseph J., PhD.	***benefits paid by UCD***	***0***
Largier, John L., PhD.	***17% of salary***	***583***
Lawrence, Cathryn A., PhD.	***17% of salary***	***2994***
Administrative Assistant	***22% of salary***	***1505***
Task 11, Report Preparation And Project Management: Travel Expenses	**Justification**	**Amount**
Task 11, Report Preparation And Project Management: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	***General office, printer and computer supplies; assumes $3000/yr and is split between UCD primary staff and programmer in proportion to the proportion of the total salary for these investigators charged as labor for this task or sub−task***	***882***
Office/Presentation Supplies	***Office, printer and computer supplies needed to prepare reports, technical memos and peer reviewed publications***	***7000***
Task 11, Report Preparation And Project Management: Subcontractors	**Justification**	**Amount**
Hendrix, Noble, PhD.	***120hrs X $87 + $ 8,472 ODC (120 hours of editing/word processing)***	***18912***
Reiser, Dudley, PhD.	***24hrs X $167***	***4008***
DeVries, Paul, PhD. P.E.	***24hrs X $127***	***3048***
Loftus, Michael, PhD.	***24hrs X $144***	***3456***
Nightingale, Tim	***24hrs X $66***	***1584***
Zablotney, Joetta,	***24hrs X $101***	***2424***
Huang, Chi−Ming, PhD., P.E.	***16hrs X $92***	***1472***
Greene, Correigh, PhD.	***40hrs X $84***	***3360***
Beechie, Tim, PhD.	***40hrs X 100***	***4000***
Task 11, Report Preparation And Project Management: Equipment	**Justification**	**Amount**
Task 11, Report Preparation And Project Management: Other Direct	**Justification**	**Amount**
Task 11, Report Preparation And Project Management: Indirect (Overhead)	**Justification**	**Amount**
	25% of total excluding equipment and subcontracts; 25% overhead charged by UCD on first $25000 of each subcontract, this overhead divided between Tasks as the proportion of the R2 and NMFS contract total completed in this Task or sub−Task	***11949***
	Task 11 Total	$95,057
	Grand Total	$754,631

− The indirect costs may change by more than 10% if federal funds are awarded for this proposal.

What is the total of non−federal funds requested? ***100***

Introduction

Over the past several decades, substantial resources have been devoted to the management of water, fisheries, and habitat in the San Francisco Bay-Sacramento River Delta (Bay-Delta) ecosystem in general, and the resident chinook salmon runs in particular. There has been increasing concern for species in decline, with the listing of winter and spring-run Central Valley (CV) chinook under both federal (Endangered Species Act, ESA) and state laws. Although mathematical models of these species have been developed both at the individual (e.g., Kimmerer 2001, Jager and Rose 2003) and the population (e.g., Botsford and Brittnacher 1998) level, management and research direction have been based primarily on qualitative compilations of what is known about these salmon runs. Research has tended to be focused on the controllable freshwater factors that could affect salmon run variability, such as flows and diversions, with less emphasis on other sources of variability such as the ocean. There have also been few attempts to understand how uncertainty in the life history of salmon and error in measurement of data may affect model predictions. For the chinook salmon runs, both management and research direction could be improved by models that more closely tie them to all of the relevant data and explicitly incorporate uncertainty in the modeling process.

Little attention has been paid to variability in survival of the ocean phase. Accounting for effects of the ten-fold variability in ocean survival would: (1) give a clearer view of other effects by reducing unexplained variability in the freshwater phase, (2) allow the potential for more efficient water management by monitoring ocean conditions and responding to fluctuating ocean conditions. Marine survival is largely determined during the period immediately following ocean entry, allowing a 2-3 year lag before relevant flows occur.

Further, ocean survival is only one example of sources of salmon mortality that should be accounted for. Persistence of salmon populations depends on total mortality from egg to spawning (Fig. 1), as well as how the various sources of mortality vary and covary. When total mortality reduces the abundance of eggs produced by an individual spawner to less than one spawner returning, the population will decline. Mortality may be "budgeted" in different ways in different years or under different management scenarios, but it is always the total that is important. Decisions regarding water management and research direction should account for mortality at all stages, even though some may be poorly understood.

The various levels of understanding should also be included; management of both Bay-Delta water and Bay-Delta research would be improved by explicit accounting for uncertainty in our understanding of the mortality budget. Decision-making for CV salmon needs a tool that can integrate the various salmon abundance indices and survival estimates in a way that combines uncertainties appropriately. There also needs to be a method for accounting for a number of different viable hypotheses regarding how water management affects salmon runs, and the evidence behind each, in Bay-Delta decision making. Decision makers need to know the risk associated with a particular action, and how they can reduce that risk through further research. Including uncertainty in descriptions of population state (e.g., probabilities of extinction), incorporating uncertainty in decision-making, and using the pattern of uncertainty to guide further research will allow management to evolve more rapidly toward better management with better models.

Here we propose to develop a statistical modeling approach to the two Central Valley chinook salmon species-at-risk (winter-run and spring-run) that incorporates mortality in all phases of salmon life history, and includes the effects of uncertainty in assessing population status, guiding future research, and making management decisions. The approach involves two categories of models: (1) at the population level we will develop an age structured model that can be easily analyzed and simulated on computers repeatedly to assess uncertainty and random variability, and (2) at the individual level we need models that link directly to the effects of management on flows, temperatures, etc. in the river and delta environment.

The first step in our approach will be development of a conceptual model of the important life stages and the data available regarding growth, survival and reproductive rates in each stage

(Task 1)(Fig. 1). This step is a necessary assessment of available data on which to base the formulation of the two models to be used at the individual and population level. An important role of this task will be to inform CalFED and the Bay-Delta modeling community of the basis for our other tasks: development of a population viability model that will initially be fit to escapement data and will account for uncertainty in parameter values (Task 2), development of new approaches to statistical analyses of existing data where needed to reflect uncertainty (Task 3), assessment of the ocean influences on CV chinook salmon, including evaluation of the potential benefits of ocean monitoring (Task 4), and modification of an existing bioenergetic model of individual salmon (Task 5). After completion of these steps, all of the results will be incorporated in a more comprehensive version of a population viability model with relevant uncertainties updated (Task 6). That model will then be used to make recommendations to improve monitoring of these species (Task 7) and to make management decisions in a way that accounts for uncertainty (Task 8). We will also develop an interactive web-based version of the model (Task 9), attend (encourage) interactive meetings (Task 10) and document our results (Task 11).

The questions we propose to answer are as follows:

(1) What is the distribution of mortality over the complete lifetime of CV salmon, how much variation is there at each stage, what are the effects of all stressors at all stages, and what is the uncertainty associated with these stressors (Fig. 1).

This will involve special emphasis on the ocean stage:

(1a) How do ocean conditions influence temporal variability in ocean survival of CV chinook salmon?

(1b) What is the likely benefit to CV water management of monitoring the early ocean conditions outmigrating salmon experience.

(2) What are the current levels of risk of extinction with uncertainty of winter-run and spring run CV chinook.

(3) What are the safe levels of each race (e.g., delisting criteria), developed in a way that uncertainty is accounted for.

(4) How do particular management actions affect performance goals (e.g. escapement) in light of uncertainty?

(5) How can research on CV salmon be directed in way that most efficiently reduces uncertainty?

Because our proposed work involves water management and salmon, and it will provide a new analytical framework relating management and research direction to what is known, it address the first and third general areas of interest to the Science Program stated in the Synopsis of the PSP. Our proposal also addresses many of the specific topics in Attachment 1. It is a "Life Cycle Model" of several "Key Species", and of necessity it must account for all "Stresses" on those species, including "Environmental Influences" and the "Effects of Diversions". It will provide "Prediction and Strategic Assessments for Water Management and will directly improve effectiveness of Monitoring" by reducing unexplained variability in populations through direct accounting for the effects of "Ocean Conditions and Fisheries on Survival" of a salmonid.

Background

Historically both winter-run and spring-run used the upstream, higher altitude tributaries of the Sacramento River, but their current extent differs greatly and their lower abundances have lead to concern and listing by both state and federal agencies (Yoshiyama et al. 1998, 2000, Lindley et al. 2004). Winter and spring-run races were separated both temporally and geographically in their spawning habitat. Winter-run chinook historically used the headwater springs, spawned in the early summer, emerged from the gravel in late summer, emigrated over the winter and entered the ocean the following spring (Lindley et al. 2004). Development of eggs was dependent on relatively constant flow and cool temperatures of the spring fed streams. Currently, winter-run are confined to spawning in the Sacramento River. Spring-run chinook used the spring flows to reach the upper tributaries of the Sacramento in summer and waited out the summer in high elevation pools. Spawning commenced in the fall and juveniles emerged the following spring. Stream residency varied and could last over a year; out-migration occurred in both spring and fall depending upon time of residency. There are currently several extant subpopulations of the spring-run (Lindley, et al. 2004).

CV chinook salmon life cycle

A useful way of viewing the chinook salmon life cycle for management purposes is in terms of a complete mortality budget. Each individual (female) produces a certain number of eggs at the end of her life, and the various sources of mortality can remove those progeny throughout her life. For the population to continue to persist, one female progeny must remain to spawn. Such accountings in a replacement context are seldom made because little is known of the mortality in some stages. However, we propose to construct such a description with specific identification of the relative amount of temporal variability in each stage, and the degree of uncertainty in each stage. The qualitative description with data sources referenced will be our life cycle model (Task 1), which will then be used to formulate and communicate our modeling approach. Here we briefly describe each stage, the data available in each stage, recent new information on each stage or the associated environment, and their implications for modeling and analysis. We use winter-run as an example here; spring-run would be similar except for timing and multiple subpopulations.

Spawning

Spawning adults produce eggs that incubate in the gravel and emerge as juveniles. Factors that may affect spawning include environmental attributes such as the quality and quantity of spawning habitat (which may be further defined as a function of river flow, water temperature, gravel size, etc.) and density dependent effects such as redd imposition. Data on winter-run redds have been collected by CDF&G by weekly aerial redd surveys (CDF&G 2004a). Although there may be problems relating redd counts to egg production (e.g. detection of redds, variability in egg deposition rates, etc.), these data can serve as an index of egg deposition to which environmental covariates can be fit.

Egg

Eggs incubate in the gravel and emerge from the gravel to rear in natal streams until migrating downstream. The factors affecting survival from incubation through the freshwater rearing stages may include redd dewatering, water temperature, rearing habitat quantity and quality (a function of stream flow, water temperature, pool availability, woody debris, etc.). Juvenile counts of winter-run chinook have been collected at rotary screw traps at Red Bluff Diversion Dam and they may be used to quantify the number of juveniles leaving the upper Sacramento traveling toward the Delta.

Juveniles in river and delta

Juveniles migrate down the Sacramento River, either remaining in the Sacramento or becoming diverted through the Delta Cross Channel (DCC) and into the North fork of the San Joaquin River. In either case, juveniles migrate through the Delta past Chipps Island and into San Francisco Bay. Unfortunately, little is known about the survival of winter-run chinook through this stage of their life history. Winter-run sized fish are captured in Chipps Island Trawls and some have been identified in the Sacramento River Trawls. These data may be useful for understanding run timing, but may not be useful for estimating survival through particular stretches of river however.

There have been some efforts to estimate how environmental conditions (salinity, turbidity, water temperature, river flow) and water management decisions (proportion of flow exported for human use and gate position at DCC) affect survival of out-migrating hatchery chinook salmon (Brandes and McLain 2001, Newman and Rice 2002, Newman 2003, Fig. 3). Newman and Rice (2002) analyzed the fate of migrating fall-run hatchery chinook released at various points in the Delta and collected as juveniles in a trawl at Chipps Island or as adults in the marine catch.

Newman (2003) also used paired releases of fall-run hatchery chinook juveniles at the entry to the Delta (near Sacramento) and at the exit of the Delta (near Benicia). Brandes and McLain (2001) consolidated the release studies to date and examined the environmental factors that might affect survival through the Delta. The results of these studies indicated that survival was negatively correlated with water temperature, positively correlated with Sacramento River flow, negatively correlated with exports, negatively correlated with DCC gate position, positively correlated with salinity, and negatively correlated with turbidity.

It would appear that this phase of the life cycle has been analyzed quite effectively; however, the results of Newman (2003) and Newman and Rice (2002) should be carefully used to parameterize the survival and migration of juvenile winter-run and spring-run chinook. The environmental conditions are different for migrating fall-run chinook than winter-run chinook; the export flows are lower, the salinity values higher, and the temperature values much higher for fall-run chinook than winter-run chinook (data in Newman 2003 and Cramer et al. 2004). Both biological and statistical problems with using the results presented in Newman and Rice (2002) and Newman (2003) are reviewed below in the Task 3. At the very least, the survival rates of out-migrating winter-run juveniles should incorporate uncertainty due to the relationship being derived from fall-run chinook migrating in the spring (rather than during the winter for winter-run chinook).

Ocean

Smolts migrating from the estuary enter the ocean phase which is probably responsible for a survival rate ranging from 0.1 to 0.01 (based loosely on survivals from coho salmon). CalFED can benefit from the results of recent research efforts on ocean influences on salmon. Since the 1970s, there has been increasing interest in the influence of ocean conditions on Pacific salmon abundance at two different time scales, inter-annual variability, and more recently decadal change (see reviews in Botsford et al. 1989, Pearcy 1992, Botsford and Lawrence 2002 and Botsford et al. 2005). For CV chinook salmon at the inter-annual scale, examination of the combined influence of upwelling, ocean temperature and sea level identified a dependence of abundance on warm/cool conditions (i.e., El Niño/La Niña) during the year of entry and the year of return (Kope and Botsford 1990). That study also identified a dependence on flows in the Sacramento River, and noted the potential confounding effects of common drivers of precipitation (hence flows) and ocean conditions.

Since the 1990s there has been increasing interest in the oceanographic basis for decadal scale changes in Pacific salmon populations, but the nature of the physical forcing and the biological effects on salmon are still poorly understood. In the 1990s a mode of variability in surface pressure fields (winds and temperatures) in the northeast Pacific that shifted in the mid-1970s was identified (the Pacific Decadal Oscillation or PDO) and was associated with opposite changes in salmon abundance in the Gulf of Alaska and the California Current (Beamish and Bouillon 1993; Francis and Hare 1994; Francis et al. 1998; Mantua et al. 1997). Since the 1990s when research efforts such as the NSF/NOAA-funded GLOBEC North East Pacific program began to focus on determining the causal links between the atmosphere, ocean physics, biological productivity and salmon abundance, a more comprehensive understanding of both physical and biological changes has evolved (e.g., Strub and James 2000, McGowan et al., 1998).

Closer scrutiny of salmon catch records indicated that California Current species differed in their response to the changes in the mid-1970s, with coho salmon declining dramatically while chinook salmon did not (Fig. 3, Botsford and Lawrence 2002, Botsford et al. 2002, Batchelder et al. 2003). The two California Current species also appear to differ in their spatial scales of variability, with coho salmon being uniform throughout their range in the CCS and chinook salmon varying on 100 km spatial scales. Various hypotheses have been advanced to explain this difference, and the explanation that it was due simply to the differences in spawning age structure has been rejected (Hill et al. 2003, Botsford et al. 2002, 2005).

In addition to these retrospective analyses of the changes in the mid-1970s, considerable attention has been focused on the more recent shift from warm to cool conditions in the late 1990s. The PDO (Mantua et al. 1997) also seemed to change at that time, but closer examination has shown that the modes of variability in pressure fields in the northeast Pacific ocean are more complex than could be described as a simple return to an earlier state (Bond, et al. 2003). However, there has clearly been a shift in biological conditions in the California Current. The community composition of zooplankton from southern California to British Columbia has changed to more cold water species (Batchelder et al. 2002, Peterson and Schwing 2003), and there has been an upturn in salmon population returns along the coast (Botsford 2002).

In addition to the information from ongoing salmon studies, the understanding of biological productivity in our local coastal ocean is also increasing due to an NSF-funded field study of the fine-scale effects of wind on coastal circulation (upwelling) and the consequent biological productivity (Wind Effects on Shelf Transport, WEST, J. Largier Senior PI, Botsford PI). Our analysis of the effects of loss of biological productivity off the continental shelf during high upwelling (Botsford et al. 2003a) provides a potential explanation for the lack of differences in early ocean growth rate of chinook salmon between a year of high upwelling and a year of low upwelling (MacFarlane et al. 2002, Botsford 2002).

As a consequence of the WEST project and increasing state and national interest in ocean monitoring, we have developed ocean observing capabilities at the Bodega Marine Laboratory. The Bodega Ocean Observing Node (BOON) is comprised of radar mapping of surface currents, a moored current profiler, and shoreline oceanographic and meteorological observations. Ongoing shoreline data on temperature and salinity date back to 1955, with continuous records of sea level, wind, meteorology, and chlorophyll fluorescence starting more recently. Radar observations started in 2001, and now give surface currents from Pt. Reyes to north of Ft. Ross. Real-time current vs. depth data from the mooring started in late 2004. Plans include nearshore wave data, salinity, temperature and fluorescence data from the mooring, and deployment of a nutrient sensor at the shoreline. This coastal ocean observing node is part of the state-funded COCMP-NC program and the federally funded CeNCOOS regional association for central and northern California, and will soon expand to provide surface currents in the Gulf of the Farallones. Ancillary regional data are available on offshore winds (NDBC buoys), offshore waves (CDIP buoy), river flow, and satellite observations.

Upstream migration

After one to four years at sea winter-run adults return through the Bay and Delta to migrate up the Sacramento River. Factors affecting the number of adults migrating to spawning grounds include straying due to flow regimes in the Delta, passage of diversion dams, harvest in the freshwater fishery, etc. Spawner abundance has been estimated for winter-run chinook from 1967 to 2003 from counts of adults passing Red Bluff Diversion Dam (Fig. 5, CDF&G 2004a). The operation of Red Bluff Diversion Dam has changed the precision of the spawning escapement estimates over this time period however. Prior to 1990, all returning spawners passed via a counting ladder. Since 1990 the gates of the diversion dam have been opened to enhance upstream survival of winter-run, which has reduced the precision of the estimates (Botsford and Brittnacher 1998). Spatial distribution, age, and sex composition of spawners may be inferred from carcass counts, which have been conducted since 1996 by CDF&G (CDF&G 2004a). The escapement data (Fig. 5) provide the longest index of abundance and are valuable for fitting population time series models, such as the Leslie matrix model that we discuss below (Task 2).

Approach

Task 1: Life cycle model

The life cycle model will catalogue the effects of environment and habitat on vital rates during each of the life history stages described above (Fig. 1), then describe the most appropriate modeling approach to integrate the various data sources from the various stages. The description of the effects of environment and habitat on vital rates in each stage will be similar, but more comprehensive, in format to the description of stages in the background section. This description and the modeling approach will be circulated and presented among the Bay-Delta modeling community for comments and feedback.

Modeling strategy

Our approach to modeling will employ two types of models. For a model which must be easily analyzed or run in simulation mode to assess the effects of uncertainty on management, we will develop an age structured Leslie matrix model, whereas for a model describing interactions between mobile individuals, under different environmental conditions, and at low spatial densities, we will develop a bioenergetic, individually based model (IBM). Because IBMs keep track of a large number of individuals, they are typically numerically demanding. Models at the population level more commonly describe the distribution of individuals over age, size, stage or space, and are focused on population behavior such as rates of increase, persistence or stability. Population models are numerically less demanding and can be analyzed or simulated many times under different conditions for the purposes of exploring probabilities of extinction, decision making, and sensitivity. The models will be linked in the sense that information gained, such as survivals resulting from simulations of the IBM under different water management scenarios, can supply an annual survival or a distribution of annual survivals to the population model.

Individual models

The use of IBM structures allows the population being modeled to represent the variability in individuals observed in field data without the need to assume underlying statistical distributions. This is particularly useful when population sizes are small and environmental variability is large (DeAngelis and Gross 1992) as is the case for CV chinook salmon. The IBMs that have been developed for CV salmon are described in Kimmerer (2001), beginning with the CPOP simulation of fall and winter-runs of CV salmon, and their responses to conditions in the Delta. Similar, more advanced models have been developed (see references in Kimmerer 2001). Of particular management interest is the application of the Oak Ridge chinook model to determine how water management in the Tuolomne River could meet the goals of adequate recruitment while maintaining phenotypic diversity (Jaeger and Rose 2003).

Many IBMs include the physiological energetics of the fish being modeled. Bioenergetic models provide a common framework for tying together information about food and feeding, temperature affects on physiological processes, the physiological costs of swimming and environmentally-cued swimming behavior. Numerous studies of salmonids in lakes, rivers, estuaries and the ocean have been conducted (e.g., Beauchamp et al. 1989, Hanson et al. 1997, Beauchamp et al. 1989, Broduer et al. 1992, Davis et al. 1998, Jager and Rose 2003) and Great Lakes populations of coho and chinook (Stewart and Ibarra 1991, Goyke and Brandt 1993, Jones et al. 1993, Rand et al. 1994, Mason et al. 1995, Mason and Brandt 1996). We developed a bioenergetic individual-based model (IBM) for juvenile salmon in the ocean, based on Stewart et. al. (1983) with the Thorton and Lessem (1978) temperature correction, and parameterized it for coho and chinook salmon (Stewart and Ibarra 1991, Brodeur et al. 1992) to investigate growth and mortality processes during early ocean life (Fig. 6). Daily ration was modeled as a temperature-dependent function of body weight (Brodeur and Pearcy 1987). We used solutions to this model as a functional framework for evaluating the existing data regarding size and time of entry and ultimate survival and age of spawning (e.g., Bilton et al. 1982, Shapovalov and Taft 1954, Holtby et al. 1990, Carnation Creek data, and 20 years of data from OPI hatcheries) in a common context. We used data from Bilton, et al. (1982) to determine the functional relationships: (1) that the fraction surviving to age 3 to spawn is an exponential function of TOE, i.e., mortality rate over the release time is a constant, and (2) when that effect is removed from the data, the fraction spawning precociously at age 2 depends on size of ocean entry (SOE) and time of ocean entry (TOE) in a way that reflects the predicted size at age 2 (Fig. 7). This shows how the initial state when entering the ocean affects the survival and age of spawning return (Fig. 8).

Tailoring our bioenergetic IBM to represent juvenile Chinook salmon in the Bay-Delta will be a key part of out modeling strategy (Task 5). We will take advantage of our GLOBEC research and develop a bioenergetic model for the estuary by re-parameterizing our ocean model. We will incorporate recent research on swimming speeds,temperature dependence and smoltification of Central Valley chinook salmon (Myrick and Cech 2002, Swanson et al. 2004, Marine and Cech 2004) and make new lab measurement for critical parameters for which no literature values are available. We will use this model of the Bay-Delta to tell what the likely effect of estuarine conditions on ocean survival and age of spawning return would be (Fig. 8). We will also use this model to give a rough estimate of how survivals from one run of interest (e.g. winter-run) might vary, when there are data from only another run (i.e., fall-run) since both size of the juveniles and the water temperature in the Bay-Delta vary significantly between runs (Fig. 3). This will allow us to evaluate the uncertainty surrounding these environmental stressors as they influence growth and survival in the estuarine phase by using these survivals and growth rates as prior distributions to refine our Leslie Matrix Model (Task 6).

IBM models are also particularly amenable to coupling into hydrodynamic models through "particle tracking" in which simulated particles are released into spatially-explicit circulation models and move within the modeled space as determined by the model hydrodynamics (e.g. Hermann et al. 1996, Weinberg et al. 2002). The structure of these models also allow environmentally-cued fish behavior to be included with relative ease so that the effects of food, temperature and behavior on growth and survival can be studied (Brandt 1993, Railsback and Rose 1999, Jager and Rose 2003, Booker et al. 2004). As part of Task 5 we will implement our bioenergetic model as a spatially-explicit individual-based model (IBM) by linking our model to the CA Department of Water Resources Delta Simulation Model (DSM2) hydrodynamic/water quality model of the estuary through their Particle Tracking Model (PTM).

Population models

A simple age structured model was developed as part of the original ESA recovery team for winter-run chinook salmon. It was used to develop delisting criteria by determining a "safe" level of abundance and growth rate, while accounting for the measurement error involved in addition to the conventional accounting of process (environmental) variability. A similar model was used by NMFS scientists to develop a monitoring strategy based on maintaining a certain statistical power (Lindley, et al. 2000). Additionally, an age structured model was constructed for winter-run chinook salmon in the Central Valley by Cramer et al. (2004), in which an accounting-based approach was used to make deterministic projections of abundance as a function of survival, maturation, and fecundity values. A Bayesian approach to fitting available population data was used to determine the effects of different levels of striped bass on the extinction rate of winter-run chinook salmon (Lindley and Mohr 2003).

NMFS scientists at the NWFSC have taken a different approach to salmon population viability analysis. In the 1980s, it was shown that the total abundance calculated from Leslie matrices with elements specified as random variables would be a lognormally distributed random variable (Tuljapurkhar 1982, Tuljapurkhar and Orzack 1980). This result led to the representation of population growth as a diffusion process (Lande and Orzack 1988), and a regression-based method for determining the growth rates of the mean and variance from time series of abundance (Dennis et al. 1991). NMFS scientists have modified that method, and have employed it as a standard means of estimating rates of growth for populations in listed ESUs (Holmes 2001, McClure, et al. 2003). Heinrichsen (2002) used the Botsford and Brittnacher (1998) model to estimate stochastic growth rate, and found that it compared poorly to results obtained using the methods of Dennis et al. (1991) and Holmes (2000). Lindley (2003) has recently developed a Kalman filtering approach that avoids some of the ad hoc assumptions that had to be made in the earlier Dennis et al. and Holmes models.

In ecology in general, there is a growing appreciation for the fact that the low level of precision in estimating probabilities of extinction make their usefulness questionable (e.g., Ludwig 1996, 1999). This appreciation for uncertainty is leading scientists to ask management-related questions regarding how best to reduce probability of extinction (even though you cannot estimate it well) (Ellner and Frieberg 2003). The use of explicit methods to account for uncertainty in the probability of extinction and to carry this uncertainty into the management decision framework is an important improvement over previous methods (Ludwig 1999).

In summary, both individual based models and population models are under active development, with an increasing emphasis on expressing and accounting for uncertainty. It is not yet clear whether it is best to represent random growth of salmon populations as a random walk or with cohort based randomness. This will be important to our project as we wish to include the effect on cohorts of randomness in early freshwater and ocean life stages. Also needed is work on how to link individual based models to population level (distribution based) models so that the advantages of both can be utilized. We will address these issues in our approach to modeling CV chinook salmon (Task 2).

Bayesian approach to uncertainty

Accounting for uncertainty is a central feature of our modeling approach. The effect of environmental, anthropogenic, and density related factors cannot be known with certainty (e.g. Minns and Moore 2003, Peters et al. 2001), therefore we will incorporate uncertainty into the modeling approach. Multiple hypotheses have been put forth to explain the population declines of natural stocks of chinook salmon, for example loss of freshwater habitat, high harvest rates, and competition with hatchery fish (Nehlsen et al. 1991). In addition, salmon migrating through the Sacramento San Joaquin Delta may face additional factors that affect survival such as entrainment in water pumping stations or diversion into irrigation canals (Brandes and McLain 2001, Baker and Morhardt 2001). The relative importance of these factors can only be tested by constructing a model (Caswell 2001, Greene and Beechie 2004). Further, the degree to which this model reflects reality can only be addressed by comparing the model predictions to observed data. The model is indefensible if it is not tied to data, because many other parameter sets can be used to produce the same results if that set of parameters facilitates a particular agenda. Confronting models with data does not remove the possibility of arbitrary interpretations, however it does provide a transparent method for testing what we think we know about the mechanisms to what we have observed (Hilborn and Mangel 1997).

We propose using Bayesian methods to incorporate uncertainty into the estimation of model parameters. Bayes theorem is

$$p(\beta \mid y) = \frac{p(\beta)p(y \mid \beta)}{p(y)} \quad , \qquad (1)$$

where y are the data, $p(y|\beta)$ is the posterior distribution, $p(y)$ is the sum (or integral) over all values of β if β is discrete (or continuous), $p(y|\beta)$ is the likelihood function, and β is the vector of coefficients that we would like to estimate. In words, Bayes theorem says that the posterior distribution is proportional to the prior times the likelihood (Fig. 9). The denominator of Bayes theorem is simply a normalization constant that ensures that the posterior distribution is a proper probability density (i.e. integrates to 1). The posterior distribution can also be viewed as a weighted average of the likelihood and the prior (Gelman et al. 1995). The weights are related to the inverse of the variance (precision) of the prior and likelihood distributions (for the case where β are Normal random variables and the variance is known, the weights are equal to the precision). The component that has the greatest information (highest precision) about the coefficient value will have a greatest contribution to the posterior distribution.

Because the Leslie matrix model will have been constructed using a Bayesian approach, we can use a component of the Bayesian method known as 'updating'. Equation (1) can be viewed from a chronological perspective (Fig. 9). The prior $p(\beta)$ is our current understanding without having seen any data. When we make one observation, we can update our prior with the data to produce the posterior via Bayes theorem. Assume we have another observation to make. Our understanding prior to making the second observation is our current understanding, which is our prior. When we make the second observation, we can update our prior with the data to produce a new posterior via Bayes theorem.

There are three primary advantages of the Bayesian approach. First, using a Bayesian approach to estimate population vital rates from empirical studies enables one to transfer the distributions for the β coefficients directly into the Leslie matrix model as priors. If additional information is obtained from fitting the Leslie matrix model to escapement data, the priors will be updated to reflect the information in the escapement data (Fig. 9). Second, we can use the empirical relationships used to estimate the distribution of the β coefficients to understand how additional sampling might decrease uncertainty in the β coefficients (Task 7, Fig. 9). Finally, the uncertainty in the state variables (e.g. population abundance) can be used directly in a Bayesian decision framework, which can evaluate the risk of particular management alternatives given uncertainty in the model (Task 8, Fig. 9).

We can also use Bayes theorem to integrate over structural uncertainty. Structural uncertainty arises from not knowing the function g that relates a population vital rate (e.g. juvenile survival S_j) or state variable (e.g. abundance of juveniles $N_{i,t}$) to a set of covariates. For example, spawning might be defined by a density independent or density dependent function, and we may not have enough information to feel comfortable deciding on one functional form. We can construct multiple models (say M_k, $k = 1,\ldots, K$) each with a different set of functions for calculating vital rates or state variables. For the Leslie matrix approach described here, each of the candidate models would produce a posterior distribution of a state variable or vital rate such as the survival of juveniles in freshwater. We could use Bayesian model averaging (Hoeting et al. 1999) to integrate across the uncertainty in the K models.

The posterior distribution of juvenile survival in freshwater incorporating structural uncertainty is a weighted average of the K posterior distributions from each of the M_k models. The weights w_k are proportional to how well the models fit the data and the prior probability placed on each model. If we had little information about one model over another, which is likely to be the case, the weights are equal to the likelihood attributable to a particular model $p(y|M_k)$ normalized by the total likelihood explained by all of the models $\sum p(y|M_k)$.

The Bayesian approach has been criticized by some ecologists (e.g. Dennis 1996) and there are weaknesses to a Bayesian approach that need to be considered. If the prior specification is too precise, the data will have little effect on updating the prior, and the posterior will look remarkably similar to the prior. Also, if there is zero probability of a particular coefficient value or state variable in the prior, the posterior will also have zero probability for that value. Therefore, specification of the prior can be a straightforward mechanism to controlling the output of the data analysis. Specification of informative priors needs to be based on a formal data analysis first, based on literature review second, and based on expert opinion last. The second two options require that additional variation be added to the prior distributions to account for their subjective nature. Using non-informative priors (e.g. a low precision parametric form or uniform distribution) is another alternative; however, the non-informative prior must be constructed carefully to specify equal probability for coefficient values (e.g. Walters and Ludwig 1994).

The integration across the normalization constant in equation (1) can be difficult and it was a barrier to using Bayesian methods on complex problems. Markov Chain Monte Carlo (MCMC) algorithms (Gilks et al. 1995) have been used successfully for numerical integration across many dimensions, but they are prone to some problems worth noting here. Unlike algorithms that return parameter values at a function maximum (such as simplex or Nelder-Mead) and are therefore useful for maximum likelihood estimates, MCMC continues to sample points from the posterior distribution while it is running. To ensure that the posterior distribution is well-sampled, multiple chains with different starting values are run. Comparison of the later stages of the multiple chains provides guidance that each chain is sampling points from the same posterior distribution. The samples that are taken between the starting value and the posterior distribution are termed the "burn-in" and are discarded. Unlike maximization algorithms, there are no stopping rules for the MCMC algorithm. After reaching the posterior distribution, one typically wants to take enough samples from the posterior distribution so that the autocorrelation within the chains can be reduced by systematically throwing some samples out (Gelfand and Smith 1990). An extra step is required when estimating the posterior distribution to ensure that estimates have converged to a stable posterior distribution (e.g. Gelman 1995). The steps required to run a Bayesian analysis are slightly more complicated than for a traditional data analysis, however we feel that the benefit of incorporating parameter and structural uncertainty by obtaining a posterior probability distribution outweighs the costs in model construction, estimation, and model checking. As an example of this approach, a Bayesian stage structured model was used to model the population dynamics of crayfish in response to hydrologic conditions in the Florida Everglades (Hendrix 2003, Fig. 10).

Task 2: The Leslie Matrix Model

The Leslie matrix model has the form

$$\mathbf{X}_{t+1}=\mathbf{A}\mathbf{X}_t, \qquad (2)$$

where **X** is a vector of population abundance at different ages, and **A** is the transition matrix that determines how the age specific abundances change each year. The transition matrix **A** is composed of survival rates in the sub-diagonal, fecundity across the top row and zeros elsewhere.

$$\mathbf{A} = \begin{bmatrix} 0 & f_2F_2 & f_3F_3 & f_4F_4 & f_5F_5 & f_6F_6 \\ S_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & S_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & (1-f_2)S_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & (1-f_3)S_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & (1-f_4)S_5 & 0 \end{bmatrix} \qquad (3)$$

where $F_a$is the fecundity at age a, f_a Is the fraction spawning at age a, and S_a is the survival from age a to age a+1. The fecundities, survival rates and fractions spawning may themselves be functions of other covariates. The elements of **A** may be time dependent as environmental covariates and water management actions (e.g. the position of the Delta Cross Channel gate) change through time. A relationship between each element of $\mathbf{A_t}$ ($A_{i,j,t}$) and a set of predictor variables for that element can be constructed

$$A_{i,j,t} = g(\beta, X_t) \qquad (4)$$

where X_t is a vector of time dependent covariates, β is a vector of coefficients, and g is a function used to describe the relationship (e.g. linear, exponential, or Beverton-Holt). The functions g will be mathematical representations of the hypotheses generated in the *Life cycle model* (Task 1), and they will be used to define different structural forms of the Leslie matrix model.

We propose to fit the Leslie matrix model to the number of spawners counted at Red Bluff Diversion Dam (for winter-run chinook), and estimate the vector of parameter values β with these data. We may use additional sources of information of adult winter-run spawners from carcass counts and redd surveys (CDF&G 2004a) by developing a statistical approach to account for the errors present in each type of index of abundance (Task 3). There are multiple sources of data for adult spring-run chinook (CDF&G 2004b, Lindley et al. 2004) that may be used to estimate β in the Leslie matrix model that will also need to be evaluated statistically. We model female spawners only, assuming that there are sufficient males to fertilize all eggs (Botsford and Brittnacher 1998). The estimates of the parameter vector β will be probability distributions that reflect uncertainty about the coefficients in the Leslie matrix model and will be estimated using a Bayesian framework. In addition, structural uncertainty will be included in the Leslie matrix model to reflect uncertainty about the function g.

There are two approaches for fitting the Leslie matrix model incorporating parameter and structural uncertainty to the data identified in Task 1. The first approach is to construct a single, complex, model for each assumption of structural uncertainty and fit this model to the several data sets simultaneously. The second approach is to fit smaller models of particular life history stages to each corresponding data set independently, and subsequently fit the Leslie matrix model using the spawner escapement data. If we use Bayesian methods and the smaller data sets are independent (i.e. freshwater survival is not correlated to oceanic survival), the two approaches will yield equivalent results. The results would not be equivalent if we used either point estimates (e.g maximum likelihood) or likelihood methods for model coefficients, however. Bayesian modeling provides an explicit method to combine two or more sources of information through updating (see Fig. 9). We will check the assumption of independence and evaluate the use the latter approach, because fitting a series of smaller, simpler models simplifies the modeling approach and facilitates assessing the contribution of each data set.

Incorporating uncertainty into the Leslie matrix model allows us to simulate population trajectories by using Monte Carlo techniques. Monte Carlo techniques are simply running the Leslie matrix model multiple times with different coefficient values β in each run. The coefficients are drawn at random from their probability distributions obtained from the Bayesian analyses. In the case of structural uncertainty, multiple Leslie matrix models are run, each with an individual set of parameter distributions, and Bayesian model averaging is used to integrate the results of each model into a final distribution for inference.

Conservation measures for Central Valley chinook

A central goal of CALFED is to determine how water management activities will affect the recovery of at-risk species. Management activities must be compared to quantitative criteria of recovery to reveal how effective each management action will be. Typical approaches to evaluating recovery include calculating the probability of extinction and the probability of delisting under different management actions (including no action). The Leslie matrix model and the parameter distributions from the retrospective analysis can be used to evaluate CALFED recovery goals.

We propose to conduct a population viability analysis (PVA) while incorporating uncertainty in the parameter values and model structure using the Leslie matrix model. We will use a threshold of 100 spawners (Botsford and Brittnacher 1998) to represent quasi-extinction, because depensatory mechanisms (e.g. Allee effects, Allee 1931) can cause populations to decrease rapidly after crossing such thresholds. Like Botsford and Brittnacher (1998), we will compare the number of spawners predicted by the Leslie matrix model in a given year to this threshold to identify cohort extinction events. When all cohorts fall below 100 female spawners, the population has reached quasi-extinction. Using the Monte Carlo approach described in the Leslie matrix model section, statements about the probability of extinction can be made in light of age at spawning and other uncertainties in the life history of winter and spring-run chinook.

Delisting criteria need to be specified so that populations that are no longer in danger of extinction in the near future can be identified and removed from public concern. The specific quantitative values that define delisting criteria have varied depending on species. A probability of extinction less than 0.1 in the next 50 years was used by Botsford and Brittnacher (1998) for winter-run chinook in the Sacramento River. We propose to use that same extinction criteria but a new analysis of the criteria necessary to reach it (i.e., the delisting criteria). Botsford and Brittnacher (1998) used an ad hoc model to account for parameter uncertainty and measurement error in determining the number of samples needed to determine that a population of winter-run chinook that had met the delisting criteria. They concluded that winter-run chinook in the Sacramento could be subject to delisting if more than 10,000 spawners were counted (with measurement error less than 25%) consecutively for 13 years. We propose to revisit the sampling criteria for delisting using the Leslie matrix model. Given 10 additional years of escapement data (under different conditions than the previous 25 years), additional research into the factors affecting ocean, Delta, and freshwater survival, and incorporating structural uncertainty, parameter uncertainty, and measurement error, it is possible that the sampling criteria for delisting would change.

We will also identify the stages of the life-cycle model that are contributing the most to the uncertainty in the number of returning spawners. Ellner and Fieberg (2003) present a PVA with uncertainty of spawning chinook salmon in the Snake River basin. They used Sobol indices, which are an analysis of variance approach (Saltelli et al. 1999), to rank the sources of uncertainty in life history stages contributing to uncertainty in the number of returning spawning salmon. This method can also be implemented with the Bayesian approach proposed here. The results of prioritizing the uncertainty in escapement as a function of uncertainty in stage specific vital rates can be used as a starting point for more formal analyses of (1) how different or additional monitoring can reduce uncertainty about key life history stages (Task 7) and (2) how management actions may affect projections of population size or key life history vital rates in light of uncertainty (Task 8).

Task 3: Statistical Analysis of Existing Data

Wherever we have data, we will attempt to estimate the coefficients of functions β between population vital rates and environmental and water management covariates. Within the life cycle model, particular life history stages (e.g. counts of juveniles passing Red Bluff Diversion Dam) or empirical data (e.g. survival of coded wire tagged smolts in the Delta) can be used to estimate the coefficient values. For example, the abundance at a life history stage can be modeled as

$$N^*_{j,t}=g(N_{j,t},\ X_t\beta) + e_t \qquad (6)$$

where $N^*_{j,t}$ are the predicted abundance of life history stage j at time t and e_t is the error between observations and predictions at time t, which is assumed to be a random variable with expected value equal to zero and an unknown variance. If the coefficients that make up β are continuous, there are an infinite number of possible combinations that can be put forth to predict $N^*_{j,t}$. Values of β can be evaluated by assuming a parametric distribution for the e_t and using a likelihood function to evaluate possible parameter sets. The most likely values of β are the maximum likelihood estimates and will occur when the $\Sigma\ e_t$ are minimized, however we may also be interested in other values of β that are almost as likely or that are up to 95% as likely.

Sampling models of observed data

We will focus on data that have been collected on adult spawners, juveniles, and to the degree that they are applicable, coded wire tag (CWT) studies of survival through the Delta. The juvenile data will be used to fit models of freshwater survival, residence time, etc. to determine stage-specific vital rates. The adult data will be used to fit the Leslie matrix model. Determining how uncertainty in observing the data affects estimates of model parameters is an important task. For example, several types of data have been collected for spawning winter-run chinook including: escapement estimates from adults passing Red Bluff Diversion Dam, carcass counts from the spawning grounds, and aerial redd counts. Each of these estimates of abundance are imperfect, therefore any model being fitted to these data should take into account the error in observation (see Hilborn et al. 1999). A formal sampling model will be constructed to estimate the variability in the data due to biological mechanisms (habitat relationships, density dependent effects, etc.) and the uncertainty in the data due to measurement error.

Data have been collected on the survival of juveniles migrating through the Central Valley and Delta that may be useful to understanding mortality of out-migrating juveniles (Newman and Rice 2002, Newman 2003). Hatchery origin fall-run chinook juveniles have been used for these analyses however, and the results of these studies should be used with care. There are at least two problems with applying the results of Newman (2003) to winter-run chinook, the first statistical and the second biological. First, water temperature (the most important covariate according to Newman 2003) experienced by migrating winter-run chinook was typically less than 14.4 ^{o}C (58 ^{o}F), which was outside the range experienced by fall-run in Newman's (2003) analysis (Fig. 3). Applying the values of temperature experienced by winter-run chinook directly (e.g. Cramer et al. 2004) may predict unreasonable estimates of survival (i.e. greater than 1). Second, because the temperatures were largely below 14.4 ^{o}C, they may not be an important environmental factor affecting winter-run juvenile survival. If this was indeed the case, then the coefficient value should actually be zero rather than the value determined for fall-run chinook (-0.56 SE = 0.10 in Newman 2003). At the very least, uncertainty should be included in any survival relationship using the fall-run survival results. Moreover, the applicability of these studies needs to be analyzed in a formal manner to determine their relevance to winter and spring-run CV chinook.

The mortality rate of out-migrating winter and spring-run chinook is largely unknown, but an important vital rate for understanding the impact of water management actions. We may be able to use the results of Newman and Rice (2002) and Newman (2003) as initial guesses at mortality rates by inflating the variance of the parameter coefficient distributions, however these rates could be updated using information from the bioenergetics model (Task 5) and information on CWT data of winter-run chinook.

Task 4 - Ocean Influences on Central Valley Chinook Salmon

Knowledge of the effects of ocean conditions on survival of CV chinook salmon can reduce unexplained variability in population dynamics and aid both research and management of water resources (Botsford 2002). Variability that can be attributed to oceanic factors will allow a clearer picture of freshwater influences and stronger conclusions from monitoring the effects of changes in management, which is a vital part of adaptive management. To accomplish a better understanding of how the ocean affects these populations, CalFED can benefit from ongoing research progress on the influence of marine physical and biological conditions on survival of Pacific salmon. One example in which we are participating is the GLOBEC North East Pacific program funded by NOAA and NSF as part of the US Climate Change research program. Here we propose: (1) retrospective analysis of existing salmon escapement data to determine possible influences of ocean conditions on Winter, Spring and Fall runs of chinook salmon in the context of management issues in the Central Valley, and (2) assessment of the benefits of future monitoring of ocean conditions to aid in future analysis and prediction of salmon abundance.

Oceanographic influences on Pacific salmon

Our approach to determining ocean influences on Central Valley chinook salmon will include a retrospective analysis of escapement data on winter-run, spring-run and fall-run. This analysis will make use of all available physical and biological data describing the state of the California Current, but we will also focus on recent, nearshore locally monitored conditions. The latter will form the basis for answering the question of what benefit CalFED can obtain from nearshore monitoring of biological conditions in the local ocean during the early ocean period of CV chinook. These efforts will be related to results from the bioenergetic model of individual salmon (see section).

The first step will be exploratory analysis of covariability between escapement data and indicators of ocean state such as the upwelling index, observations of sea level height and ocean temperature records. We will compute correlations between population and ocean data, accounting for the effects of intra-series correlation (Pyper et al. 1999, Botsford and Paulsen 2000). Where there are different potential subpopulations (Lindley et al. 2004), such as in the spring-run, we will analyze each series separately to determine possible differences such as those detected for Columbia River spring/summer chinook salmon on the Columbia River (Botsford and Paulsen 2000). In all series we will account for known non-stationary effects, such as catch and large changes in water management (e.g., improvement in conditions for winter-run chinook in the 1990s). We will also account for changes in the methods of gathering data, such as the changes in the times the gates of the Red Bluff Diversion Dam were open. Population dynamics will be accounted for either by using residuals from fits to stock-recruit relationships or other means.

This exploratory analysis will lead to candidate time series for fitting population models to the escapement data. The history of such analysis has primarily a linear orientation, as correlation coefficients respond to linear relationships, but may not detect a quadratic (e.g., dome-shaped) relationship. There have been a few similar analyses to detect such dome-shaped relationships (e.g., Cury and Roy 1989), but there is also a developing interest in the more general area of fitting nonlinear models to time series and other ecological data (Burnham and Anderson, 2002; 2004), which allows the maximum likelihood estimation of parameters of interest.

Recent progress in this area (de Valpine and Hastings, 2002; de Valpine, 2004) has been able to explicitly include both environmental noise (e.g., physical environmental forcing) and measurement error (e.g. lack of precise estimates of salmon population numbers) in nonlinear (density-dependent) models, which goes beyond earlier work (e.g. Higgins et al. 1997) that only included environmental noise. The underlying concepts of using maximum likelihood based approaches to obtain the best fit for a single model, and information criteria (see reviews in Burnham and Anderson 2002, Bjørnstad et al. 2004) to choose amongst models are relatively straightforward. The most recent work (e.g., de Valpine 2004) has developed practical methods for applying this concept, based on Markov Chain Monte Carlo (MCMC) methods to help in the step of maximizing likelihoods. Thus, these methods are now ready to be applied to complex problems of the kind arising in the analysis of data obtained through GLOBEC (and earlier data) and can be used to obtain quantitative parameter estimates.

Potential for local monitoring

In conjunction with these regional retrospective correlation and model fitting studies, we will focus on the influence of local ocean conditions in the Gulf of the Farallons on the CV stocks. We will address the question of whether there is an advantage of local monitoring of ocean conditions to prediction and management of CV salmon. In addition to the fact that salmon of each species have a common response to warm/cool conditions in the local ocean, runs in different rivers respond differently due to differences in freshwater conditions and local ocean conditions. There is a strong possibility that CalFED can benefit from the monitoring program BOON at the Bodega Marine Laboratory. Observations of surface currents can be used to estimate potential movement of smolts exiting the Golden Gate, and how it varies from year to year. Monitoring will also yield some estimate of interannual variability in general biological productivity. This effort will be aided by the emerging results from the WEST program.

Our approach to assessing the potential of local monitoring will be to use the data collected over recent years to determine how they are related to CV salmon returns and the state of salmon juveniles collected in NMFS trawls. First, chlorophyll fluorescence was monitored from May 2001 through 2003, and that monitoring has recently begun again, and will continue indefinitely. Surface currents from high frequency (HF) radar and flows indicated by the BOON current profiler as interpreted with results of WEST analysis, will give us information on how fluorescence at the BOON mooring reflects general biological productivity in the Gulf of the Farallones region. That information can be compared with spawning returns from 2003-2005. Values of productivity from the redeployment of the current meter in 2005 can be compared to returns from 2007 on. The results obtained from such direct comparisons over the term of the proposed work will be augmented by relating other longer term local series to productivity, based on our WEST findings regarding conditions leading to greater amounts of productivity.

Comparison of these results with those obtained from NMFS sampling in this region will provide a context in which to assess the various salmon growth rates observed in those samples. The ocean bioenergetic model in our GLOBEC research indicates that growth rates can affect survival to spawning return and the age of spawning. The fact that local high winds provided a possible explanation for not seeing a difference in growth rates between a high upwelling (La Niña) year and a low upwelling (El Niño) year provides some optimism that we may detect local effects that indicate local monitoring may be advantageous to CV salmon management (Botsford 2002).

Task 5: Bioenergetic IBM modeling

Bioenergetic models provide a common framework for tying together information about food and feeding, the physiological effects of temperature, the physiological costs of swimming and the physiological consequences of environmentally-cued swimming behavior. Since the CV chinook salmon we will model have both a relatively small population size and are subject to large and spatially-explicit variability in stressors such as temperature, an IBM is a particularly appropriate model formulation for this Task. (DeAngelis and Gross 1992). As reviewed above, we have found using our GLOBEC bioenergetic IBM to be a powerful tool for integrating existing data on the influences of size and time of ocean entry on survival and spawning maturation schedule (Figs. 7 and 8) and other salmon population behavior (Hill, et al. 2003, Botsford and Lawrence 2005). In the past year, we have explored the interactions between currents and salmon swimming behavior by "swimming" salmon particles in CODAR fields off the coast north of Point Reyes (Fig. 11) and in current fields from the GLOBEC ocean circulation model (Botsford et al. 2003b).

Approach to bioenergetic IBM

We propose to modify our salmon bioenergetic individual-based model (IBM) developed in the GLOBEC program to make it more applicable for modeling the juvenile stages of chinook salmon in the lower rivers and the Delta. This model, described above, is essentially the same as "the Wisconsin model" (Hanson et al. 1997) but coded in a format that makes it easy to modify and to embed into hydrodynamic/temperature models. Our model uses parameter values from the literature, all of which are for adults and many of which were developed for salmonids other than coho and chinook salmon. This type of model has been shown to be reasonably accurate for adult chinook salmon despite using some parameters measured for other salmonids (Madenjian et al. 2004). However, the problem of applying a model of adults to juveniles has not been addressed for salmonids. There is a substantial literature base that shows that bioenergetic models developed for a particular life-stage do not accurately simulate other life-stages (see Whitledge et al. 2003 and references therein); however, this fact is generally ignored. Likewise, the importance of laboratory evaluations of bioenergetic models to assure their accuracy for particular applications is also known but ignored (e.g., Ney 1993, Bajer et al. 2003). We will gather from the literature any newly available juvenile salmon bioenergetic data pertinent to juvenile chinook salmon and use these data to improve our model parameters. As reviewed above, one of us (Cech) has already supervised laboratory bioenergetic studies of the influence of food and temperature on growth rate and smoltification of juvenile CV chinook salmon . We will incorporate these results into our model and Cech will guide an evaluation of the bioenergetic model, based on physiological energetic principles to identifthe parameters likely to be quite different for adults and juveniles. In the summers of 2006 and 2007 Cech will supervise measurement of these physiological parameters for juveniles in his fish ecophysiology laboratory. Funding for an undergraduate student assistant is requested for two summers to conduct the needed laboratory experiments.

As we did in our previous work in the lower rivers and Delta (Weinberg et al. 2003) and in our GLOBEC project we will embed our bioenergetic IBM into simulated hydrodynamics of the Bay-Delta by using "particle tracking" to link our IBM to flow and water quality fields. This will make our models spatially-explicit so that we can take advantage of the spatially explicit data on salmonids in the estuary (e.g., the CWT data) and on stressors such as temperature to evaluate the survival and growth rate effects of various water management scenarios. We plan to use the California Department of Water Resources (DWR) model DSM2 (Delta Simulation Model 2) to model hydrodynamics and temperature fields; this model is very similar to but somewhat less mathematically complex than the ROMS (Regional Ocean Modeling System) hydrodynamic/water quality models we currently use in our GLOBEC and WEST ocean modeling projects (see Task 4 for a description of these projects). We will also use the DWR Particle Tracking Model (PTM) which tracks passive particles within the hydrodynamics and water quality fields produced by DSM2, to link our bioenergetic model to the DSM2 results. Using DSM2/PTM is very similar to the particle tracking of juvenile salmon in ROMS code and CODAR fields as we do in our GLOBEC project (see Fig. 11) and to previous work on Dungeness crab on the California coast (Botsford et al. 1994a). We already have familiarity with

DSM2 as Lawrence has taken the DSM2 tutorial course. Since the PTM already has the "hooks" in its model code for running biological models in conjunction with the particle tracking and for adding swimming "behavior" as a velocity component, we believe that running our salmon bioenergetic IBM with PTM is well within our expertise. It will provide a framework to incorporate important laboratory results about the swimming behavior of juvenile Central Valley chinook (Swanson et al. 2004). It is clear that particle tracking models of juvenile chinook salmon in the estuary must include an active behavioral component since simulations of passive neutrally-buoyant particles do not reproduce the comparatively rapid observed transit times through the estuary estimated from CWT data (Baker and Morhardt 2001). In addition to the Swanson et al. result on swimming orientation, we will investigate a series of simple juvenile swimming behaviors (e.g, Webb 1995).

While we will be using DSM2/PTM as a spatially-explicit framework for our bioenergetic IBM, our experience from our GLOBEC and WEST projects has shown us that the effort required to produce meaningful results from models in which hydrodynamics and biology are being explicitly modeled can be disproportionately large. We have found that simplified but physics-based spatially-implicit model configurations can be a more efficient approach to develop an understanding of important mechanisms (e.g., Botsford et al. 2003a). As such, we will be very targeted in the types of simulations we conduct with PTM/DSM2 using our bioenergetic IBM and the total number of these simulations we run will be guided by a "cost/benefit" time assessment early in the project of this approach versus a spatially-implicit approach.

We will start our spatially-implicit modeling effort using important environmental factors found by Newman (2003) as inputs to the bioenergetic IBM so that we can model growth rates. Transit times through the estuary will be estimated from CWT data (from http://www.delta.dfg.ca.gov/usfws/maps/index.htm and direct data requests to state and federal agencies); temperature fields will be spatially explicit and will be extracted from available databases (e.g http://iep.water.ca.gov/data.html). We will compare the modeled growth rates to empirical values from Macfarlane and Norton (2002) and other data such as CWT, splitting the data into separate data sets for model fitting and refinement and model validation. The most complete data are available for hatchery fall-run fish and we will start with these. It is important to note, however, that emigrating juveniles occupy the estuary during all months and that ocean-type (most fall-run) and stream-type (most winter- and spring-run) transit the estuary at very different sizes (Johnson et al. 1992, Brandes and McLain 2001) and estuary temperatures (Fig. 3). We will use this model is to give a rough estimate of how temperature-dependent growth rates and survivals from one run of interest (e.g. winter-run) might vary, when there are data from only another run (e.g. fall-run). This will allow us to evaluate the uncertainty surrounding these environmental stressors as they influence growth and survival in the estuarine phase by using these survivals and growth rates as prior distributions to refine our Leslie Matrix Model (Task 6). We will also be able to calculate the size and time of ocean entry (SOE and TOE) for the various runs and use these as inputs to Task 4.

A critical component of the bioenergetic modeling (Task 5) will be the evaluation of the IBM modeling strategy (Task 5.1); this will include a technical memorandum describing our modeling plan. We will circulate this memo within the CalFed community to solicite feedback on our plan and to help us identify the specific management issues and scenarios of most interest to the community at the time this project is funded. Incorporation of feedback from the community will undoubtedly strengthen this modeling component.

Task 6: Model Refinement and Linkage

Development of the Leslie matrix model will occur iteratively. The initial model structural equations will be generated from hypotheses in Task 1 ; however, as the statistical data analyses are completed, the results of the bioenergetics model become available, and the ocean survival relationships discovered, there will be a need to update the Leslie matrix model to incorporate advances in these components of the life cycle.

The statistical data analysis will likely increase the certainty in population vital rates. Initial versions of the Leslie matrix model will have non-informative prior distributions (uniform or large variance parametric distributions) placed on stage vital rates (e.g. freshwater survival of rearing juveniles) for which there are little information. Data relevant to those stage vital rates may be used to construct informative prior distributions in the *Statistical Data Analysis* (Task 3). We use Bayesian updating (Fig. 9) to decrease the uncertainty in stage vital rates over time by incorporating additional data.

The results of the bioenergetics IBM will be a series of spatially explicit trajectories of fish moving through the Delta. Integration over individual behavior forms the basis for understanding demographic stochasticity in the population. The results of these analyses will have to be incorporated into the Leslie matrix model with some care, however, because the range of behaviors in individuals are dependent upon the assumptions and parameter values used to construct the IBM. Still, the results of the bioenergetic IBM can be used to describe the range of juvenile survival migrating through the Delta. The usefulness of the bioenergetics results will be to bracket the range of survival values that are consistent with the energetic demands of juvenile salmonids. We see this as an improvement to the existing conditions where little is known about juvenile survival.

The results of fitting the ocean conditions to escapement data or residuals from fits to stock-recruit relationships (e.g. Botsford and Paulsen 2000), will lead to posterior densities of oceanic survival. The survival distributions can be used directly in the Leslie matrix model through Bayesian updating (Fig 9). Alternatively, the Leslie matrix model may have to be modified to include covariates identified in the ocean influences task (Task 4). The matrix model would be refit to the escapement data so that variability could be attributed to oceanic and freshwater factors appropriately. Nearshore ocean monitoring may also be combined into the Leslie matrix model, particularly if covariates describing this life history stage are strongly correlated with escapement or spawner per recruit ratios.

Task 7: Improve Monitoring using Model

Once we have constructed a model that incorporates uncertainty, we can use that model to rank the uncertainty in life history stages that contribute to uncertainty in the adult spawner counts. Statistical tools have been used elsewhere to evaluate uncertainty in a quantity of interest (e.g. probability of extinction) from multiple sources. Ellner and Fieberg (2003) used Sobol indices (Saltelli et al. 1999) to rank uncertainty in the mean population growth rate of a generic Pacific chinook stock, and Peters and Marmorek (2001) used Categorical Analysis Regression Trees (CART) to identify the most influential uncertainties on the probability of recovering spring and summer chinook salmon in the Snake River. Once an ordered list is compiled of the sources of uncertainty and how they affect the uncertainty in a performance measure (e.g. probability of extinction or population size), how does one go about reducing the uncertainty about the performance measure?

Collecting additional data on influential life history stages may improve understanding and reduce uncertainty in the performance measure. For example, monitoring of juvenile out-migrants from natal streams might be improved by proposing to use a screw trap on a particular tributary of the Sacramento River. Another method that might reduce uncertainty is to run an experiment. For example, Newman (2003) used a paired release experiment of CWT fall-run chinook to explore the factors affecting juvenile survival through the Delta. An experiment similar to this might be proposed for hatchery origin winter-run chinook. How many samples are needed? How often should the collections be made? What sort of error can we expect in the observations? Depending on how the data are collected, it is possible that additional monitoring or experimentation may not actually help reduce uncertainty in the performance measure. Therefore, we propose to create a sampling model that would simulate data collection or experimental results to evaluate their efficacy at reducing uncertainty in a performance measure.

We will frame our approach in terms of the question: "what data would we have to collect for the posterior to have less uncertainty than the prior?" To implement this approach, we consider the sampling model and the Leslie matrix model. The sampling model consists of a specified number of samples and a probability distribution from which the samples are drawn. To obtain a hypothetical set of observations **x'**, we sample from the probability distribution the specified number of times. To calculate a predicted posterior distribution of the Leslie matrix parameter vector β given a new set of observations, we use the output of the Leslie matrix model from the retrospective analysis as our prior $p(\beta)$. We then update the prior with the set of observations from the sampling model using Bayes Theorem (see Fig. 9). We compare the Leslie matrix prior $p(\beta)$ to the predicted posterior $p(\beta| \mathbf{x'})$ to determine if uncertainty has been reduced by using the hypothetical set of observations.

Task 8: Decision analysis to evaluate recovery of Central Valley chinook

Model output with uncertainty can be used in a formal decision analysis framework. Multiple recovery strategies may be suggested, and there needs to be a formal way of evaluating each alternative in light of the uncertainty in the system. There are three reasons to perform a decision analysis while incorporating parameter and structural uncertainty: (1) robust decisions can be made over a range of different underlying assumptions (2) decisions can be made before critical events occur (i.e. extinction) by examining a no action rule alongside alternative actions and (3) the act of incorporating uncertainty allows many stakeholders to become involved in the process (Peters and Marmorek 2001).

To perform a decision analysis there must be a set of actions $\{a_1, a_i, \ldots a_N\}$. We also need a loss function that describes the loss incurred when the true state of nature (e.g. true population size) is θ, and we perform action a. For example a loss functions may be squared loss $l(\theta, a) = (\theta - a)^2$ or absolute loss $l(\theta, a) = |\theta - a|$. We also need a sampling distribution, which is the likelihood of observing data **x** given that the true state of nature is θ, $h(\mathbf{x}|\theta)$. We also need a decision rule $d(\mathbf{x}) \rightarrow a$, which converts the observed data into an action (Carlin and Louis 2000). In a Bayesian decision analysis, all of the information about θ is contained in the posterior distribution of θ, $p(\theta|\mathbf{x})$. The posterior distributions for θ, which can be calculated by Bayes theorem (eq 1). The posterior risk is

$$\int l(\theta, d(\mathbf{x}))p(\theta \mid \mathbf{x}) \qquad (5)$$

(Carlin and Louis 2000). In short, we calculate the posterior risk (a single value) by making a decision and integrating the losses incurred over the possible states of nature. The posterior risk can be minimized by choosing different decision rules d that minimize equation (5). In practice, the data **x** have indicated that the species is threatened or at risk of extinction and multiple actions a_i are proposed. The risk of obtaining a particular performance measure (e.g. probability of delisting in 20 years) is calculated under action a_i. We then compare the risks among actions to determine the most appropriate action given the parameter and structural uncertainties.

Decision analysis has been used to evaluate management actions for Pacific chinook salmon. The Plan for Analyzing and Testing Hypotheses (PATH) evaluated the effect of three alternatives (no action, smolt transportation, and breaching four dams) on the probability of quasi-extinction and the probability of recovery of Snake River chinook (Peters et al. 2001, Peters and Marmorek 2001). The alternatives were evaluated in light of uncertainty about model parameters, model functional forms, and hypothesized future conditions. The management alternatives were compared to each other by calculating the expected probabilities of extinction and recovery (performance measures) for each action and the distribution of these performance measures over the uncertainties listed above. Their results suggested that transportation would not substantially increase the probability of recovery or decrease probability of extinction, whereas breaching dams could have a positive effect on both performance measures. In a didactic paper, Ellner and Fieberg (2003) evaluated four management actions (no action, increase parr to smolt survival, reduce hatchery release, and eliminate harvest) incorporating uncertainty in parameter estimates. They evaluated the effect of management actions on the mean population growth rate and found that the results were equivocal; Monte Carlo simulation results of all actions had 90% confidence intervals that included no improvement in mean growth rate. However, comparisons of actions within Monte Carlo draws of parameter estimates (i.e. within a given state of nature) indicated that all actions improved the mean growth rate relative to no action. We propose to conduct a Bayesian decision analysis to identify management actions that will be robust to assumptions in biological mechanisms and uncertainties in states of nature.

Task 9: Web Page and Web-based interactive model

Dissemination of information requires that it be presented in an accessible format. We will make our web page the hub of communicating the results of our research. We feel that the best way to learn is to play. We have proposed a series of models to understand the viability of chinook populations in the Sacramento River, to quantify the oceanic impacts to survival, to modify existing monitoring programs, and to analyze management decisions. These models are largely scientific in nature. By scientific we mean that the parameter coefficients are founded on substantial data analyses and technical details. Particularly with the inclusion of Bayesian methods, the models become unfriendly to the biology community and certainly the greater public. Therefore we propose to develop an interface between the scientific models that we have described and the public that might benefit from using them.

The results of the Monte Carlo runs to examine the uncertainty in performance measures (such as adult escapement) will be prohibitively expensive to run through a web-based application. Instead, the general model structure can be explained and results from the analyses supplied in an interactive map-based approach. The architecture for this sort of data base query approach has been used successfully elsewhere. Perhaps the easiest example is the web pages devoted to listing real estate. Potential buyers can select a region and then observe information for particular houses (e.g. http://www.windermere.com). When a particular house is selected via address or by selecting a location, a host of information opens including graphics and statistics about the location.

The second objective of the interface would be to run the multiple structural Leslie Matrix models deterministically under modification of particular aspects of the management system. For example the user would be given options to modify the position of the Delta Cross Channel gate, the gate position at Red Bluff Diversion Dam, the release schedule at Shasta Dam, the commercial fishery regulations, etc. The user would be given a list of possible Leslie models to run prospectively given the management actions. The results of each model would be presented alongside the others to show how different assumptions in the structural equations affects the population. Interactive approaches and gaming can be an effective way to present the trade-offs between management actions and population effects

Personnel and Budget Justification

We are requesting funding for a Project Scientist, Dr. Lawrence, to work with Prof. Largier, Prof. Cech and Prof. Botsford on the analysis of ocean effects, the potential for ocean monitoring and the bioenergetic IBM. We also require funds for N. Hendrix to develop the statistical model working with Prof. Botsford. Dr. Hendrix is on a subcontract to R2 Resource Consultants, Inc.. Dr. Hendrix possesses expertise in the area of Bayesian estimation, which is not commonly available at universities or among consulting companies, and he was selected specifically for that skill and his knowledge of population dynamics. We have worked with him in the past on a project involving the population dynamics of zooplankton. In addition to Dr. Hendrix's expertise, we will also benefit from expertise of two of his colleagues at R2 as reviewers of the Life Cycle Model and various support people (e.g., GIS) at R2. These selections satisfy the University Guidelines as laid out in UC Davis, Office of Research Directive 98-079. We are also requesting funds for two NMFS scientists who are actively working on recovery of salmon and their ecosystems. These scientists will provide advice on model formulation during Task 1 and review project deliverables throughout the timeline (Fig. 12). An undergraduate student is required for lab experiments to determine bioenergetic parameters, working with Prof. Cech. We will need a standard, high-end computer for the modeling calculations at UC Davis. The extensive modeling will require two months of a programmer's time each year. The support for an Administrative Assistant is for assistance in integration of the semi-annual reports. We are requesting $3,000 in travel for travel to one scientific meeting per year, and one trip per year to R2 in Seattle. The salaries of Prof. Cech and Prof. Botsford are covered by UC. Salaries assume a 3 % increase per year, benefits for salaried personnel are 17%, and the overhead rate is the negotiated CalFED rate of 25%.

Project Management Plan

Louis W. Botsford (PI) will be responsible for overall project management. There will be an annual meeting in Davis of the Davis PIs and analysts, and at least Hendrix from Seattle, but often others, such as one or both of the NMFS scientists. .In addition to those fixed meetings, Botsford and Lawrence will travel to Seattle once per year for consultation with R2 and NMFS personnel, and Hendrix will travel to Davis once per year, Throughout the life of the grant we will begin planning for each bi-annual report 6 months ahead of time. These reports will be placed on our web page. Where appropriate, we will publish results in refereed journals.

We will begin with a meeting in Davis of all of the Davis PIs and Noble Hendrix to review the timeline and to define and integrate the work of each in the immediate future. That will be followed by a meeting in Seattle of R2 participants, NMFS participants and Botsford and Lawrence from Davis. Botsford and Largier will meet initially to discuss on-going monitoring, and will communicate at least monthly regarding the retrospective analysis of ocean effects. We will begin work on Task 1 and the retrospective analyses in Task 4, with weekly meetings between Botsford and Hendrix (by phone), and Botsford and Lawrence. In current and past research projects we have found that weekly meetings between the senior PI and the analysts are essential to maintaining progress. Task 1 will involve considerable communication with other Bay-Delta researchers and agencies, and travel by Hendrix to central California. About midway through the first year Hendrix, Lawrence and Botsford will begin joint planning of the report on Task 1, at the end of year 1. It will be a summary of available data, how we plan to use it and the plan for bioenergetic and population models.

In the second year, communication will be similar, with Hendrix working on Tasks 2 and 3 with Botsford, and Lawrence working on Task 5 with Botsford. Later in that year,, Hendrix, Lawrence, Largier and Botsford will carry out the fitting of the population model to ocean data. Lawrence Largier and Botsford will begin work on local monitoring in the waning days of the second year.

In the third year, Lawrence, Largier and Botsford will meet weekly to discuss progress on the assessment of potential benefits of ocean monitoring. Hendrix and Botsford will focus on Tasks 7 and 8. Hendrix will develop the web-based model of Task 9 in year 3 with assistance from Lawrence.

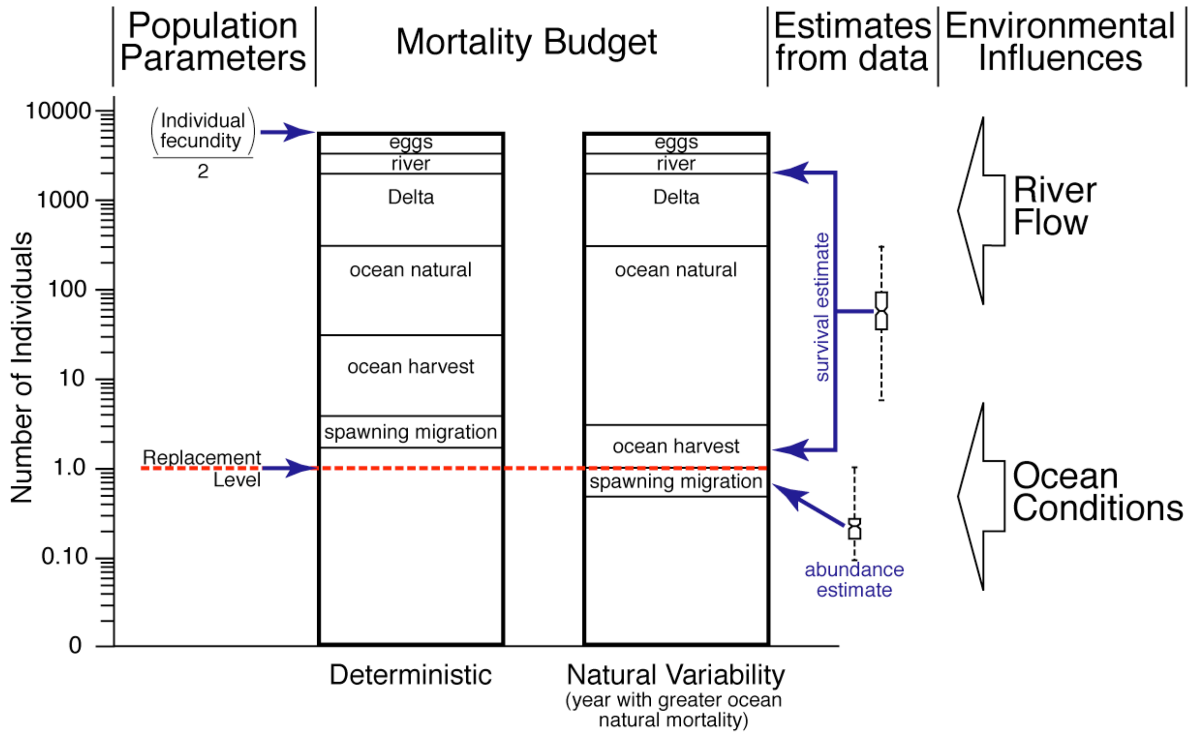

Figure 1: The mortality budget of a CV chinook salmon. If the total lifetime mortality reduces the number of progeny from (individual fecundity) /2 to less than 1.0, the population will decline because individuals are not replacing themselves. The right had column shows that the total can vary from year to year. The examples of estimates of survival and abundance and box plots indicate our uncertainty in this budget.

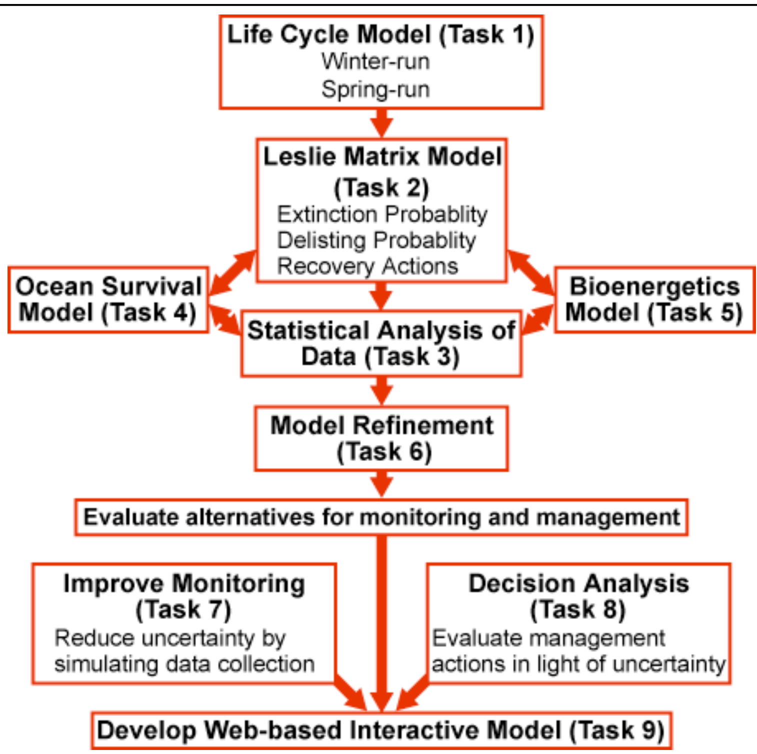

Figure 2: Schematic of proposed tasks and the flow of information between them. Hypotheses generated in the Life Cycle model will be used to construct structural relationships between environmental covariates and management actions in the Leslie matrix model. The Leslie matrix model will include uncertainty in the structural equations and in the model coefficients. Statistical analysis, an oceanic survival model, and a bioenergetics model will be used to refine the original Leslie matrix model. The updated model can be used to prioritize monitoring and evaluate management actions.

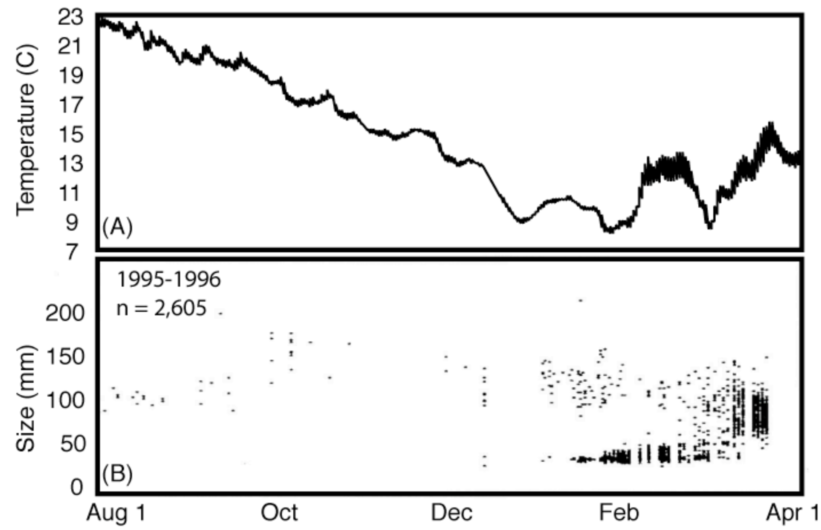

Figure 3: (A) Water temperatue at Rio Vista and (B) sizes of juvenile chinook salmon captured at Chipps Island 1995-1996. Panel A) data obtained from the IEP database (http://www.iep.ca.gov/), panel B) modified from Brandes and McLain (2001). Note that juveniles are sampled in the Delta throughout the year although size varies seasonally. Fish < 80 mm are generally ocean-type fall-run, whereas larger stream-type fish are from various runs.

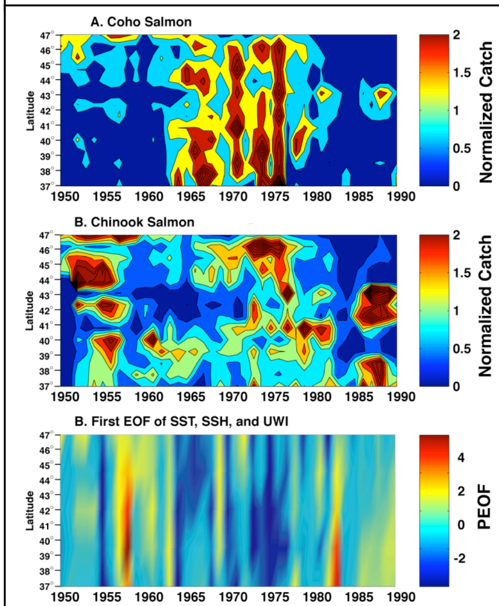

Figure 4: Spatio-temporal variability in populations of California current coho and chinook salmon as depicted in normalized (each series divided by its mean) catch data. Both populations are driven by cool/warm conditions in the CCS, but they respond on different temporal and spatial scales. The spatio-temporal variability in ocean conditions is shown as PEOF, the first empirical orthogonal function (principal component), of sea surface temperature (SST), sea surface height (SSH) and upwelling index (UWI). The PEOF show the warm/cool ENSO cycle with El Nino events being "red" and La Nina events being "blue."

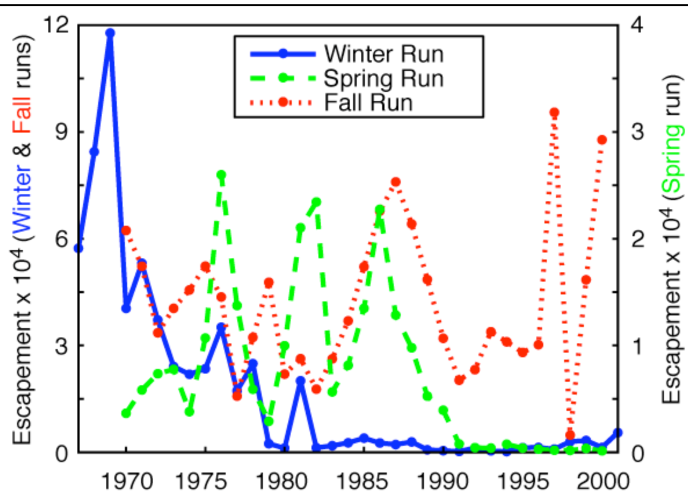

Figure 5: Escapement as observed at Red Bluff Diversion Dam. Dam operation changed in 1990 and observations after this time are less precise.

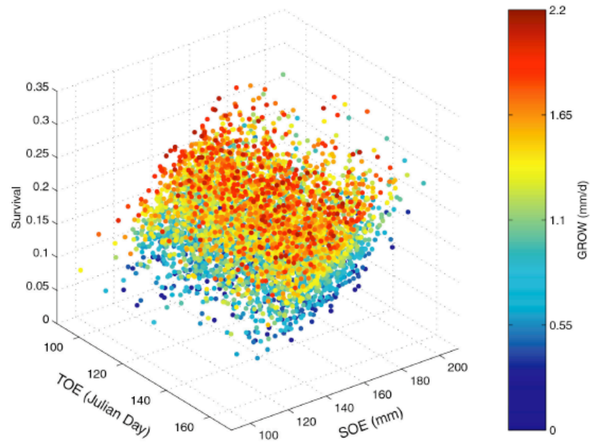

Figure 6: Survival of juvenile salmon through their first ocean summer as a function of time of ocean entry (TOE) and size of ocean entry (SOE) and growth rate (color) from our bioenergetic individual-based model (IBM) of early ocean juvenile salmon. Diet ration and diet energetic content were held constant, temperature was sampled as normal distribution of ocean sea-surface temperature from Pacific Grove, CA. The mortality model was continous and size dependent.

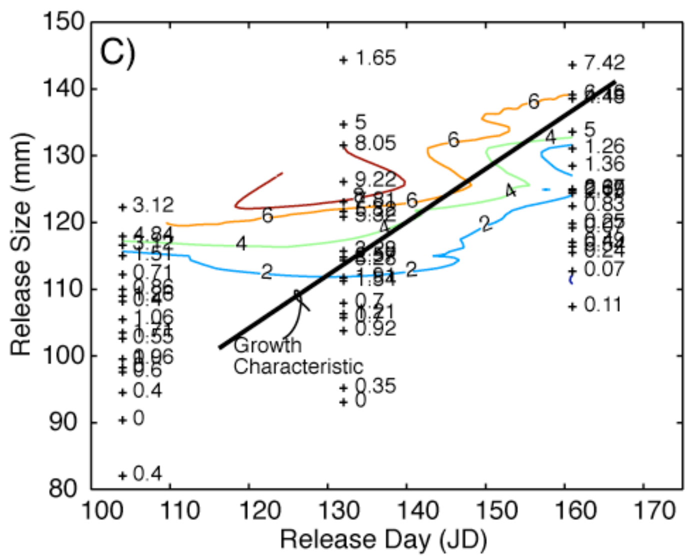

Figure 7: Conditions for precocious spawning of coho salmon as determined from the contoured data of Bilton et al. (1992). Contours of fraction of a cohort spawning precociously as a function of SOE and TOE, after the effects of TOE on mortality have been removed. Note that the combination of SOE and TOE that determines precocious spawning roughly follows the typical growth characteristic.

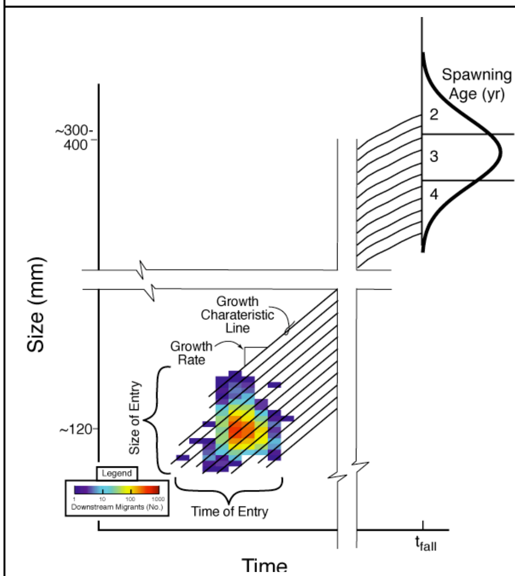

Figure 8: Conceptual view of the effects of initial conditions and early ocean conditions on early growth and subsequent population dynamics of salmon. The spawning age distribution depends on the growth characteristic (i.e., the size vs. time) on which a fish is introduced into the ocean, and the way in which physical and biological conditions affect that path (i.e., affect growth rates). This is based on results such as Fig. 7 and the bioenergetic model, and motivates ongoing work on the population dynamic effects of time-varying maturity schedule. This figure does not include the effects of varying growth rate on survival.

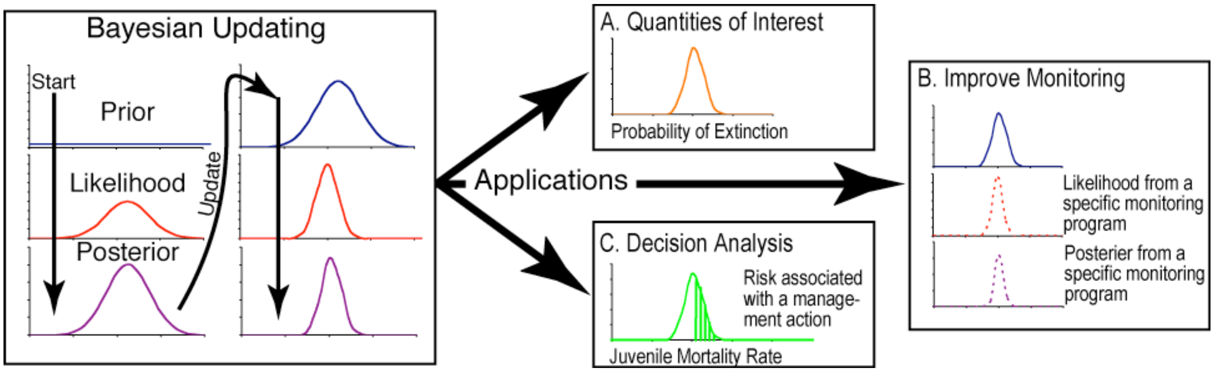

Figure 9. Left Panel: In Bayesian Updating, the prior is combined with the likelihood to produce the posterior. The old posterior becomes the prior when additional information is obtained. The old posterior is combined with the likelihood to produce a new posterior distribution. The new posterior distribution can be used for inference regarding quantities of interest, proposed monitoring designs, and formal decision analyses.

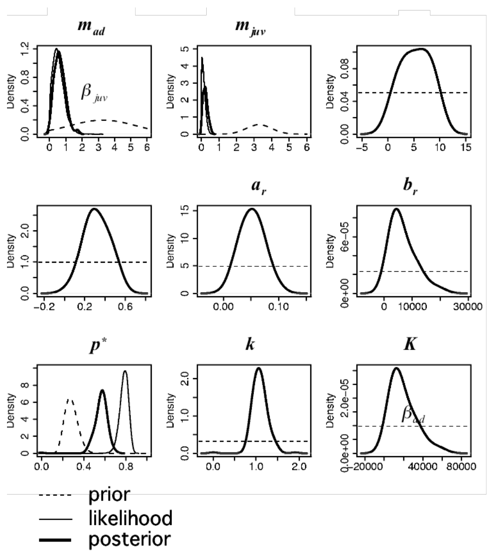

Figure 10. Prior, likelihood, and posterior distributions for population vital rates of Everglades slough crayfish (*Procambarus fallax*) estimated in a Bayesian framework. The population model was composed of the following coefficients: logit(survival)=$\boldsymbol{m} + \boldsymbol{\beta}$*months-flooded for adult (*ad*) and juveniles (*juv*), ***a*** and ***b*** are production and capacity parameters, respectively of the the Beverton-Holt stock production equation, $\boldsymbol{p}^*$ is the proportion of juveniles maturing to adults, ***k*** is an over-dispersion parameter relating to a negative binomial error distribution, and ***K*** is the carrying capacity in a 2500 m^2 cell calculated from the ***b*** coefficient**.** Figure from Hendrix, A.N. 2003. Crayfish (*Procambarus* spp.) response to hydrologic restoration of the Florida Everglades. Dissertation, University of Washington, Seattle, WA.

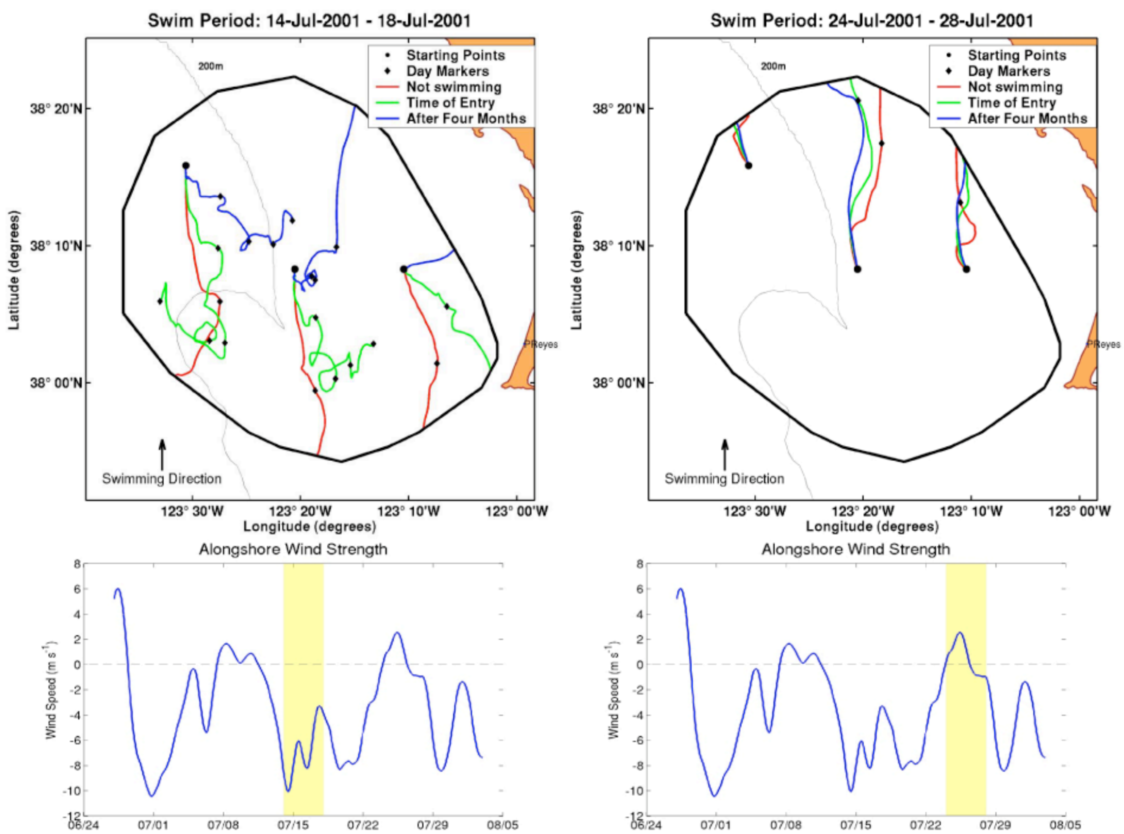

Figure 11: Comparison of transport of juvenile salmon during active upwelling (left) and relaxation of upwelling winds (right) from a particle tracking model. Swimming velocity is a function of body length calculated from an individual-based growth model and surface current fields are from high frequency radar (CODAR). Field studies indicate that after entering the ocean, juveniles swim northward, but are able to achieve net northward movement only after becoming large enough to overcome the predominately southward flows (Fisher and Pearcy 1988, Pearcy 1997). Here we test this locally, comparing "no swimming" to the "northward swimming" for fish at the size of ocean entry and the size at the end of the summer ("after Four months").

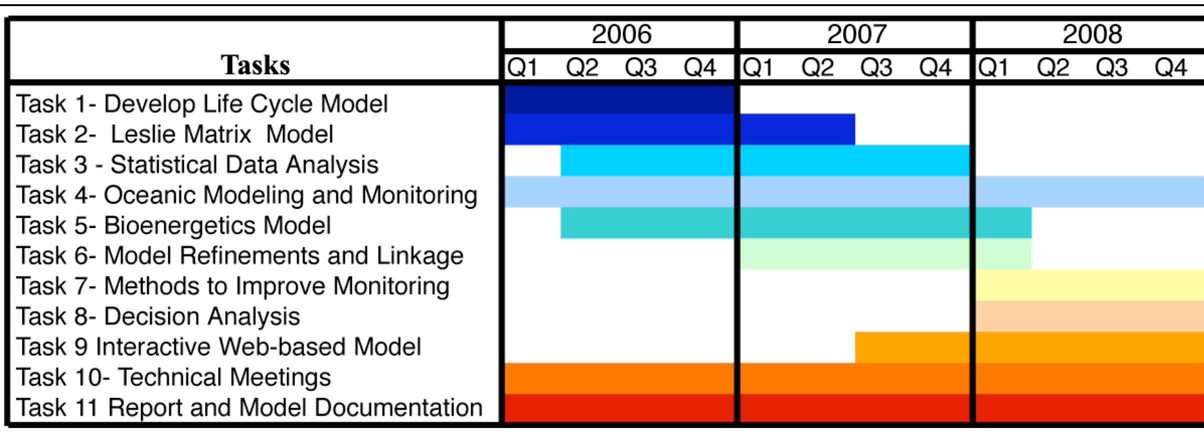

Figure 12: Project timeline.

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Kope, R. G., and L.W. Botsford. 1990. Determination of factors affecting recruitment of chinook salmon (*Oncorhynchus tshawytscha*) in central California. US Fisheries Bulletin 88:257-269.

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Botsford, L.W, R. D. Methot, Jr., and J. E. Wilen. 1982. Cyclic covariation in the California king salmon, *Oncorhynchus tshawytscha*, silver salmon, *O. kisutch*, and Dungeness crab, *Cancer magister*, fisheries. Fishery Bulletin 80(4):791-801.

Botsford, L.W and D. E. Wickham. Correlation of upwelling index and Dungeness crab catch. US Fishery Bulletin 73(4):901-907.

Activities

Service on Recovery Team for Winter Run Chinook Salmon in the Central Valley. Led effort to derive Delisting Conditions.(see Botsford and Brittnacher 1998 above)

2001-2003- Service on a Science Committee for Implementation of California's Marine Life Protection Act to guide the implementation of a system of marine reserves.

Collaboration with the Point Reyes National Seashore to develop GIS tools for the design of sustainable marine reserves. 2002-present

Service on a committee for the National Academy of Sciences to produce a report on the definition of "best available science" for fishery management, 2003-2004.

Service on team to certify Alaska salmon fisheries as sustainable under the Marine Stewardshp Council (www.msc.org), 1999-2004

Service on committee reviewing the NMFS program on ocean influences on salmon at the NWFSC, 2003.

Served in PATH (Program for Analysis and Testing of Hypotheses) regarding status and management decisions for spring/summer Chinook salmon on the Columbia River (See Botsford and Paulsen 2000 above.

JOSEPH J. CECH, JR.

EDUCATION

B.S. University of Wisconsin, Madison, 1966 (Zoology)
M.A. University of Texas, Austin, 1970 (Zoology)
Ph.D. University of Texas, Austin, 1973 (Zoology)

POSITIONS

Resident Zoologist, Sea Search I, R/V Dante Deo, Caribbean Sea and S. Pacific Ocean, 1965-66; Research Asst., Univ, Texas Marine Sci. Inst., 1966, 1968-72; Teaching Asst., Univ. Texas, 1967; Research Assoc. Univ. Texas Marine Sci. Inst., 1973; Research Assoc., The Research Institute of the Gulf of Maine, 1973-1975; Lecturer, Univ. Maine at Portland-Gorham, 1975; Asst. Professor 1975-1981, Assoc. Professor 1981-1987, Professor of Fisheries Biology, Univ. California, Davis, 1987-present; Associate Editor, *Transactions of the American Fisheries Society*, 1991-1993; Chair, UC Davis Dept. Wildlife, Fish, and Conservation Biology, 1992-1997; Member, *Copeia* Editorial Board, 1997-1998, 2000-2002; Director, UC Davis Center for Aquatic Biology and Aquaculture, 2002-present.

AWARDS AND HONORS

Member: Phi Sigma, Phi Kappa Phi, Sigma Xi; NIH Predoctoral Fellow 1970-73; Invited participant: NATO Advanced Study Institute on Environ. Physiol. Fishes, 1979, Lennoxville, Quebec; NATO Advanced Research Workshop on Evol. Biol. Primitive Fishes, 1985, Bamfield, B.C. Canada; IUPS Discussion Panel on Controversies: Circulation and Respiration, 1986, Vancouver, B.C.; Organizer: 2nd Biennial International Symposium on "Fish Physiology, Toxicology, and Water Quality Management", 1990, Sacramento, Calif.; Invited speaker: 3rd Biennial International Symposium on "Fish Physiology, Toxicology, and Water Quality Management, 1992, Nanjing, PRC; Fellow: American Institute of Fishery Research Biologists, 1992; Honorable Mention, Most Significant Paper in *Transactions of the American Fisheries Society*, Vol.121, 1992; Outstanding Faculty Adviser Award, College Agric..Environ. Sci.: 1992-93; Plenary speaker, "High Performance Fish" First International Fish Physiology Symposium, Vancouver, B.C.: 1994; Excellence in Fisheries Education Award (with P.B. Moyle), American Fisheries Society, 1995; Fellow: American Association for the Advancement of Science, 1996; Oustanding Mentor Award: UC Davis ProFemina Research Consortium 1997; Mentoring for Professional Diversity Award: Equal Opportunities Section, American Fisheries Society, 1999. Award of Excellence, California-Nevada Chapter, American Fisheries Society, 2000; Congressional Legion of Honor, Physiology Section, American Fisheries Society, 2000; UC Davis Prize for Teaching and Scholarly Achievement, 2001; USDA Excellence in Teaching Award, Western Region, 2003.

SELECTED PUBLICATIONS (since 1990, from >125 peer-reviewed articles and books)

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Danley, M.L., S.D. Mayr, P.S. Young, J.J. Cech, Jr. 2002: Swimming performance and physiological stress responses of splittail exposed to a fish screen. N. Amer. J. Fish. Manage. 22:1241–1249.
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Brick, M.E. and J.J. Cech, Jr. 2002. Metabolic responses of juvenile striped bass to exercise and handling stress with various recovery environments. Trans. Am. Fish. Soc. 131:855-864.
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Suchanek, T.H., P.J. Richerson, D.C. Nelson, C.A. Eagles-Smith, D.W. Anderson, J.J. Cech, Jr., R. Zierenberg, G. Schladow, J.F. Mount, S.C. McHatton, D.G. Slotton, L.B. Webber, B. J. Swisher, A.L. Bern,and M. Sexton, 2003. Evaluating and managing a multiply stressed ecosystem at Clear Lake, California: A holistic ecosystem approach. pp. 1239-1271. In : D.J. Rapport, W.L. Lasley, D.E. Rolston, N.O. Nielsen, C.O. Qualset,and A.B. Damania (eds.) Managing for healthy ecosystems. Lewis Publ. Boca Raton.
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Houck, A.G. and J.J. Cech, Jr. 2004. Effects of dietary methyl mercury on juvenile Sacramento blackfish bioenergetics. Aquat. Toxicol. 69:107-123.

Mayfield, R.B. and J.J. Cech, Jr. 2004. Temperature effects on green sturgeon bioenergetics. Trans. Am. Fish. Soc. 133:961-970.

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Young, P.S., C. Swanson, and J.J. Cech, Jr. 2004. Photophase and illumination effects on the swimming performance and behavior of five California estuarine fishes. Copeia 2004(3):479-487.

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Cech, J.J., Jr., M. McEnroe, and D.J. Randall. 2004. Coho salmon haematolocigal, metabolic and acid-base changes during exercise and recovery in sea water. J. Fish. Biol. 65:1223-1232.

Cech, J.J., Jr. and S.I. Doroshov. 2004. Environmental requirements, preferences, and tolerance limits of North American sturgeon. pp. 73-86. In: F.W.H. Beamish, G. LeBreton, and R.S. McKinley (eds.) Biology of North American Sturgeon and Paddlefish. Kluwer Publ. Dordrecht.

Roessig, J.M., C.M. Woodley, J.J. Cech, Jr., and L. Hansen. 2004. Effects of global climate change on marine and estuarine fish and fisheries. Rev. Fish Biol. Fisheries (in press)

Lankford, S.E., T.E. Adams, R.A. Miller, and J.J. Cech, Jr. 2004. The cost of chronic stress: impacts of a non-habituating stress response on metabolic variables and swimming performance in sturgeon. Physiol. Biochem. Zool. (in press)

Swanson, C., P.S. Young, and J.J. Cech, Jr. 2004. Integrating physiological and behavioral approaches to protect endangered species. Trans. Am. Fish. Soc. (in press)

Myrick, C.A. and J.J. Cech, Jr. 2004. Temperature effects on juvenile anadromous salmonids in California'a central valley: what don't we know? Rev. Fish. Biol. Fisheries (in press)

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Education

1987	Ph.D., Oceanography, University of Cape Town, South Africa.
1983	B.Sc.(Hons), Applied Maths, University of Cape Town, South Africa.

Professional Appointments

2004-ongoing	Associate Professor, Bodega Marine Laboratory, University of California (Davis).
1988-2004	Research Oceanographer, Scripps Institution of Oceanography, University of California (San Diego), USA.
1995-1999	Senior Lecturer, Department of Oceanography and Department of Environmental & Geographical Science, University of Cape Town, South Africa.
1984-1988	Researcher, National Institute for Oceanology, Council for Scientific and Industrial Research, South Africa.

Professional Experience, Memberships, Honors

2003-	Advisory Board, CI-CORE – CalState Universities coastal monitoring initiative.
2002	Co-editor of book (with J.C. Castilla): The Oceanography and Ecology of the Nearshore and Bays in Chile, Ediciones Universidad Católica de Chile, Santiago.
2001-	Clean Water Task Force (City of San Diego).
2001-	Clean Beach Task Force (State of California).
2001-2004	Lead PI, NEOCO, UC-funded coastal observing initiative.
2001	Aldo Leopold Leadership Fellow – Ecological Society of America.
2000-2005	Lead PI, WEST (NSF/CoOP): Wind Events and Shelf Transport.
1999-2004	PI, Scripps Shore Station Program (87-yr record, daily ocean temp/salinity).
1998-2004	NCEAS working groups on marine reserves.
1999-2003	Advisory Board, PISCO – Packard-funded consortium on nearshore ecology.
1998	Reviewer, FONDAP Humboldt Current Studies (Chile).
1995-ongoing	Research, teaching, and training in South Africa, Namibia, Chile.
1995-99	Advisory Board, Centre for Marine Studies (UCT).
1995-99	FRD, Marine & Coastal Resources (S. Africa): Chair, sub-committees "Ocean dynamics & coastal geomorphology" and "The coast as a resource".
1994-97	Associate Editor, Estuaries, Estuarine Research Federation (USA).
1993	Editor, special issue of Estuaries, 16(1): Estuarine Fronts.
1993-96	Committee, University of California Sea Grant.

Research Publications

Roughan, M., J.L. Largier, L. Clarke, M.L. Carter, 2004. Estuarine dispersion and flushing times during stratified and non-stratified conditions: Mission Bay (CA). (in preparation).

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Largier, J. and A. Boyd. 2001. Drifter observations of surface water transport in the Benguela Current during winter 1999. South African Journal of Science 97:223-229.
D'Sa, E. J., S. E. Lohrenz, J. H. Churchill, V. J. Asper, J. L. Largier and A. J. Williams 2001. Chloropigment distribution and transport on the inner shelf off Duck, North Carolina. Journal of Geophysical Research 106(C6):11581-11596.
Cudaback, C. N. and J. L. Largier. 2001. The cross-shelf structure of wind- and buoyancy-driven circulation over the North Carolina inner shelf. Continental Shelf Research 21:1649-1668.
Penven, P., C. Roy, A. Colin de Verdiere and J. Largier, 2000. Simulation of a coastal jet retention process using a barotropic model. Oceanologica Acta 23:615-634.
Largier, J. L., C. Attwood and J.-L. Harcourt-Baldwin. 2000. The hydrographic character of Knysna Estuary. Transactions of the Royal Society of South Africa 55:107-122.
Shanks, A. L., J. L. Largier, L. Brink, J. Brubaker, R. Hooff. 1999. Demonstration of the onshore transport of larval invertebrates by the shoreward movement of an upwelling front. Limnology and Oceanography 45:230-236.
Rennie, S. E., J. L. Largier and S. J. Lentz. 1999. Observations of a pulsed buoyancy current downstream of Chesapeake Bay. Journal of Geophysical Research 104(C8):18227-18240.
Monteiro, P. M. S. and J. L. Largier. 1999. Thermal stratification in Saldanha Bay (South Africa) and subtidal, density-driven exchange with the coastal waters of the Benguela upwelling system. Estuarine Coastal and Shelf Science 49:877-890.
Chadwick, D. B. and J. L. Largier. 1999. Tidal exchange at the bay-ocean boundary. Journal of Geophysical Research 104(C12):29901-29919.

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Botsford, L. W., C. L. Moloney, J. L. Largier and A. Hastings. 1998. Metapopulation dynamics of meroplanktonic invertebrates: the Dungeness crab (Cancer magister) as an example, p. 295-306. In: G. S. Jamieson and A. Campbell (Eds.), Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management, Canadian Special Publications on Fisheries and Aquatic Sciences 125.

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Graham, W. M. and J. L. Largier. 1997. Upwelling shadows as nearshore retention sites: the example of northern Monterey Bay. Continental Shelf Research 17:509-532.

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Chapman, P. and J. L. Largier. 1989. On the origin of Agulhas Bank bottom water. South African Journal of Science 85:515-519.

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Carter, R. A., H. F. McMurray and J. L. Largier. 1987. Thermocline characteristics and phytoplankton dynamics in Agulhas Bank waters. In: A. I. L. Payne, J. A. Gulland and K. H. Brink (Eds.), The Benguela and Comparable Ecosystems, South African Journal of Marine Science 5:327-336.

Largier, J. L. 1986. Structure and mixing in the Palmiet Estuary, South Africa. South African Journal of Marine Science 4:139-152.

CATHRYN A. LAWRENCE
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Education

PhD, Ecology, 1995. University of California, Davis.
Dissertation: Plankton Ecology in a Desert Saline Lake with Emphasis on Diazotrophic Cyanobacteria.

BS, (Cooperative Plan), Applied Biology, 1988. Georgia Institute of Technology.
Cooperative Employer: Georgia Environmental Protection Division, Atlanta, GA.

Positions

Postgraduate Researcher, 1997-present. University of California, Davis.
Invited Scientist, 1996. Isaac Newton Institute for Mathematical Sciences, Cambridge University, Cambridge, England
Postdoctoral Researcher, 1995-1997. University of California, Berkeley.
Field Director and Research Assistant, Pyramid Lake Research Project, 1989-1995. University of California, Davis.
Environmental Specialist (Aquatic Toxicity), 1988-1989. Georgia Environmental Protection Division, Atlanta, GA.
Research Assistant, 1985-1988. School of Applied Biology, Georgia Institute of Technology.
Environmental Technician, 1984-1987. Georgia Environmental Protection Division.
Engineering Assistant, 1983-1987. Drake and Funsten Engineers, Atlanta, GA.

Areas of Research Focus

Primary research focus on plankton ecology with emphasis on developing a quantitative understanding of the influence of environmental variability on plankton and associated populations. Projects since 1997 at UC Davis have focused on developing 1) coupled biological-physical mathematical models of environmental influence on estuarine larval fishes and coastal ocean plankton and 2) on data analysis and mathematical modeling of how climate influences Pacific Ocean salmon.

Peer Reviewed Publications (some under the name C. L. Rhodes)

Botsford, L. W. and C. A. Lawrence. Differences in dynamic response of California Current salmon species to changes in ocean conditions. Deep-sea Research, Part II. (In Press).

Jost, C., C. A. Lawrence, F. Campolongo, W. van de Bund, S. Hill and D. DeAngelis. 2004. The effects of mixotrophy on the stability and dynamics of a planktonic food web model. Theoretical Population Biology 66:37-51.

Botsford, L. W., C. A. Lawrence, E. P. Dever, A. Hastings and J. Largier. 2003. Wind strength and biological productivity in upwelling systems. Fisheries Oceanography 12: 1-15.

Botsford, L. W. and C. A. Lawrence. 2002. Patterns of co-variability among California Current chinook salmon, coho salmon, Dungeness crab, and physical oceanographic conditions. Progress in Oceanography 53: 283-305.

Botsford, L. W., C. A. Lawrence, M. F. Hill, A. Hastings and K. S. McCann. 2002. Dynamic response of California Current populations to environmental variability. pp 215-226 *In* N. A. McGinn (ed.), Fisheries in a Changing Climate. American Fisheries Society Symposium 32, Bethesda, MD.

Weinberg, M., C. A. Lawrence, J. D. Anderson, J. R. Randall, L. W. Botsford, C. J. Loeb, C. S. Tadokoro, G. T. Orlob and P. Sabatier. 2002. Biological and economic implications of Sacramento watershed management options. Journal of the American Water Resources Association 38:367-384.

Rhodes, C. L., J. E. Reuter, M. E. Lebo and C. R. Goldman. 1996. Spatial and temporal variations in nitrogen fixation in Pyramid Lake, NV: potential influences of past climates, *In* L.V. Benson (ed.), A Workshop on Ongoing Paleoclimatic Studies in the Western Great Basin. USGS Circular 1119.

Lebo, M. E., J. E. Reuter, C. R. Goldman and C. L. Rhodes. 1994. Interannual variability in a desert lake: influence of regional climate. Can. J. Fish. Aquatic Sci. 51:862-872.

Lebo, M. E., J. E. Reuter, C. R. Goldman, C. L. Rhodes, N. Vucinich, and D. Mosely. 1993. Spatial variations in nutrient and particulate matter concentrations in Pyramid Lake, Nevada during a dry period. Can. J. Fish. Aquatic Sci. 50:1045-1054.

Reuter, J. E., C. L. Rhodes, M. E. Lebo, M. Kotzman, and C. R. Goldman. 1993. The importance of nitrogen in Pyramid Lake (Nevada, USA), a saline, desert lake. Hydrobiologia 267:179-189.

Lebo, M. E., J. E. Reuter, C. L. Rhodes, and C. R. Goldman. 1992. Nutrient cycling and productivity in a desert saline lake: Observations from a dry, low-productivity year. Hydrobiologia 246:213-29.

Selected Seminars and Presentations (some under the name C. L. Rhodes)

Lawrence, C. A. 2004. Influence of physical and biological model structure on results of coupled biological-physical models of wind-driven upwelling in the coastal ocean. Takashi Asano Seminar Series, Civil and Environmental Engineering, University of California, Davis. [Invited]

Lawrence, C. A., L. W. Botsford, A. Hastings, E. P. Dever and J. Largier. 2004. Influence of physical and biological model structure on results of coupled biological-physical models of coastal upwelling. 2004 Ocean Sciences Meeting, AGU, Portland, OR.

Botsford, L. W, C. A. Lawrence, M. F. Hill and A. Hastings. 2004. Comparative analyses of the response of California Current chinook and coho salmon to the regime shift of the mid-1970s. 2004 Ocean Sciences Meeting, AGU, Portland, OR.

Botsford, L. W., J. L. Largier, D. M. Kaplan and C. A. Lawrence. 2003. Simulating juvenile salmon growth and swimming in a near shore flow field. Joint Cal-Neva Meeting of the American Fisheries Society. San Diego, CA, April 2003.

Lawrence, C. A., L. W. Botsford, M. F. Hill and A. Hastings. 2002. Responses of California Current populations to environmental variability. 2002 Ocean Sciences Meeting, ASLO/AGU, Honolulu, HI.

Lawrence, C. A. and L. W. Botsford. 2001. Influence of size and time of ocean entry on survival and precocious maturation of CCS coho salmon. 3rd Salmon Ocean Ecology Meeting, Seattle, WA.

Lawrence, C. A. and L. W. Botsford. 2000. Size and time of ocean entry as determanints of survival and precocious maturation in CCS coho salmon: a modeling and retrospective analysis. 2000 Ocean Sciences Meeting, ASLO/AGU, San Antonio, TX.

Lawrence, C. A. and L. W. Botsford. 2000. Salmon Population Dynamics: US GLOBEC retrospective and modeling studies in the California Current ecosystem. PICES IX Annual Meeting, Hakodate, Japan.

Lawrence, C. A. and L. W. Botsford. 1999. Growth and mortality of coho salmon during initial ocean entry: an individual-based modeling study. Gordon Research Conference: Coastal Ocean Modelling. New London, NH.

Rhodes, C. L. and L. W. Botsford. 1998. Individual-based models of coho salmon during initial ocean entry. 45th Annual Eastern Pacific Ocean Conference (EPOC), Timberline Lodge, Mt. Hood, OR.

Rhodes, C. L. and L. W. Botsford. 1998. Survival of coho salmon during initial ocean entry: dynamical consequences of size-dependent mortality and environment dependent growth rate. Annual Meeting, Ecological Society of America, Baltimore, MD.

Rhodes, C. L. and L. W. Botsford. 1998. A coupled biological-physical model of striped bass (*Morone saxatilis*) eggs and larvae in the Sacramento/San Joaquin River/Delta System. 1998 Ocean Sciences Meeting, ASLO/AGU, San Diego, CA.

NOBLE HENDRIX, Ph.D.
Biometrician/Aquatic Ecologist

Dr. Hendrix has applied his training and experience as both a biostatistician and aquatic ecologist to rivers and lakes, estuaries, and marine ecosystems in the Pacific Northwest and southeastern United States. Experience with Bayesian statistics allows him to incorporate uncertainty into statistical population models to enhance the decision-making process. He has worked with a variety of ecological and fishery data specializing in constructing statistical models in a probabilistic framework. The ability to quantify uncertainty allows him to develop robust study designs that are responsive to data gaps and avoid the ambiguity of results inherent to many field studies. His experience with field investigations and frequent interactions with both technical and laypersons gives him the background needed to write coherent descriptions of these methods and to communicate study results to decision-makers.

EDUCATION

Ph.D. (Fisheries/Aquatic Science) University of Washington, 2003
M.S. (Fisheries/Aquatic Science), 2000
B.S. (Zoology) Duke University, 1992

PROFESSIONAL AFFILIATIONS

American Statistical Association
The Ecological Society of America

ADDITIONAL TRAINING

Bayesian Hierarchical Modeling, American Statistical Association Continuing Education
Spatial Statistics Department of Natural Resources, Cornell University
Programming with Avenue, the ArcView GIS scripting language, ESRI
Spatial Statistics Workshop in winBUGS, NMFS

EXPERIENCE

Statistical Skills: Dr. Hendrix has constructed and implemented experimental designs, analyzed data using linear, non-linear, time-series, and geostatistical models. He is currently using time series models to examine potential synchronous relationships in coho and Chinook adult returns to Pacific Northwest streams. He is also using geostatistical models to explore the spatial autocorrelation in pacific hake fish density in the California current and is experienced in variogram estimation and kriging. Linear time-series models were used to identify changes in aquatic invertebrate species composition in response to hydrological changes associated with water management decisions. Bayesian methods were used to analyze the survival of salmonids as a function of stream reach characteristics, to quantify the uncertainty in population dynamics, and to analyze the probability of presence or absence of indicator invertebrates. He designed a multi-year monitoring study of invertebrates in three ecotones of the Florida Everglades by employing a nested design. Data were analyzed using generalized linear models with a Poisson error structure. He has used Splus/R extensively, and is proficient in Bayesian Inference Using Gibbs Sampling (BUGS) and Auto-Differential Model Builder (AD Model Builder).

Statistical Modeling: Dr. Hendrix has constructed quantitative population models, selected among competing models using information criteria, constructed a spatially explicit population model, and evaluated alternative hydromanagement scenarios incorporating uncertainty. He has used quantitative models including: fishery biomass dynamics models, Deriso delay-difference models, growth models such as Gompertz and von Bertalanffy, recruitment models such as Beverton-Holt and Ricker, and size, stage, or age structured population models including fishery catch at age/size assessment methods. When modeling aquatic populations, he prefers to use probabilistic methods incorporating either likelihood or Bayesian approaches where applicable. This approach allows competing models to be compared by Akaike's or Bayesian Information Criteria. He is currently involved in modeling the size distribution of meso-zooplankton in the California current as sampled by an Optical Plankton Counter and determining the population vital rates of a multi-species assemblage using auxiliary net tow information.

Aquatic/Marine Ecology and Fisheries: Dr. Hendrix has extensive experience in designing, conducting and analyzing the results of riverine, estuarine, and marine ecosystems. He has wide-ranging field experience in the Pacific Northwest including: conducting stream morphology assessment for sections of South Prairie Creek, Washington, sampling Dungeness crab megalopae in near surface plankton bongo nets; using otter trawls to sample fish and invertebrate assemblages in Washington and Oregon estuaries; sampling crabs in Puget Sound, Washington with SCUBA; and collecting and preparing English sole from Eagle Harbor, Washington (Superfund site) for histological analyses. His experience includes designing and implementing experiments of substrate preference by intertidal crabs, and evaluating the effects of hydrology on invertebrate mortality through simulated drought experiments under laboratory conditions.

Computers and Data Management: He has extensive knowledge of S/Splus/R for data manipulation and simulation, working knowledge of Avenue (scripting language for ArcView GIS) and Visual Basic, and basic knowledge of java, C++, and html. He has extensive use of Word, Excel, PowerPoint, and Star Office and has working knowledge of Access and Stella.

PUBLICATIONS AND RECENT PRESENTATIONS

Hendrix, A. N., and R. Hilborn. 2003. Constructing Spatially Explicit Population Models with Uncertainty. International Workshop on Bayesian Data Analysis, Santa Cruz, California.

Hendrix, A.N. 2003. What do Jazz, Ecological Modeling and Crayfish have in common? Biology Departmental Seminar, Florida International University, Miami, Florida.

Hendrix, A. Noble. 2003. Crayfish (Procambarus spp) response to hydrologic restoration of the Florida Everglades. Ph.D. dissertation. University of Washington, Seattle, Washington, USA.

Hohler, D. T. Ashwood, J. R. Richardson, L. M. Olsen, A. N. Hendrix, and A. Williams. 2003. Data Issues p. 180-208 *In* Effective Ecological Modeling for Use in Management Decisions, V. Dale (ed.). Springer-Verlag, New York, New York.

Hendrix, A. N. 2002. Environmental variation and dynamic coexistence of two crayfish species in the Florida Everglades. Quantitative Seminar Series. School of Aquatic and Fisheries Sciences, University of Washington, Seattle Washington.

Hendrix, A. N. 2002. What is Kriging? Quantitative Seminar Series. School of Aquatic and Fisheries Sciences, University of Washington, Seattle Washington.

Hendrix, A. N. 2001. Spatial statistics for the spatially challenged: using canonical correspondence analysis to partition spatial patterns. Quantitative Seminar Series. School of Aquatic and Fisheries Sciences, University of Washington, Seattle Washington.

Hendrix, A.N. and W. F. Loftus (2000) Distribution and relative abundance of the crayfishes *Procambarus alleni* (Faxon) and *P. fallax* (Hagen) in southern Florida. Wetlands 20: 194-199

Hendrix, A. N. (2000) Population size and life-history parameters of the Everglades crayfish, *Procambarus* spp. M.S. thesis, University of Washington, Seattle, WA.

DUDLEY W. REISER, Ph.D. – PRESIDENT
Senior Fisheries Scientist

Dr. Reiser is a fisheries scientist with more than 25 years experience designing, implementing, and managing fisheries and aquatic ecology projects, and habitat and instream flow assessments. His particular areas of expertise include fish ecology (anadromous and resident species), habitat assessments and criteria development, endangered species evaluations, assessments of flow regulation on fish populations and habitats, fisheries habitat enhancement, fisheries engineering, instream flow studies, assessments of sedimentation impacts on aquatic ecosystems, and flushing flow studies (related to sediment deposition).

EDUCATION

Ph.D. (Forestry, Wildlife and Range Sciences – major in fishery resources) University of Idaho, 1981
M.S. (Water Resources) University of Wyoming, 1976
B.A. (Zoology) Miami University, Ohio, 1972

PROFESSIONAL AFFILIATIONS AND CERTIFICATIONS

Certified USFWS IFIM Course - Computer Modeling (201), IFIM:IFG210, SNTEMP (310)
Certified USFWS Course - Expert Witness Seminar
Certified SCUBA DIVER - PADI and YMCA
American Fisheries Society (AFS), Certified Fisheries Scientist (No. 1447)
Society of Environmental Toxicology and Chemistry
Co-editor, Sustainable Fisheries – Pacific Salmon, Lewis Publishers.
Past Member Editorial Board, "Rivers: Studies in the Science, Environmental Policy, and Law of Flowing Waters" (ongoing member since 1992)
Member, ESA Task Force for the City of Seattle – 1994
Member, CALFED Ecosystem Roundtable Committee focused on review and prioritization of restoration projects in the San Francisco Bay-Delta Area (1998).
Member, NRDA Practitioner Group (2000-2001), AdHoc Industry Natural Resource Damage Group
Independent Science Panel (ISP) – Washington State – appointed by Governor Gary Locke to serve on Salmon Recovery Science Panel, Term: 1999-2003; reappointed through 2006.

EXPERIENCE

Habitat Modeling, Instream Flow and Flushing Flow Determinations: Extensive experience in the area of habitat and instream flow assessments in Alaska, California, Colorado, Idaho, Montana, New York, Vermont, North Carolina, Oregon, Washington, and Wyoming. Has applied a variety of IF methods including the USFWS IFIM/PHABSIM, Tennant (Montana) Method, Wetted Perimeter (WP), Trout Cover Rating (TCR), Toe-width, R-2 Cross Method, and the New England Method. Project Manager and Principal-in-charge of one of the largest instream flow studies conducted in North America; the study was conducted as part of the Snake River Basin Adjudication and included over 1100 basins within the Salmon and Clearwater basins of Idaho. Other recent instream flow projects directed by Dr. Reiser include: an assessment of instream flow requirements below Madison Dam, Montana (conducted for the Montana Power Company), instream flow study on Ward Creek below Connell Dam and Whitman Creek below Whitman Dam near Ketchikan, Alaska (conducted for Ketchikan Public Utility), determination of flow recommendations for the Duck Valley Indian Reservation, Nevada and Idaho (for the BIA), and instream flow recommendations related to the Klamath River Basin. Completed four studies related to flushing flows, including the development of guidelines for recommending flushing flows, and formulation of specific flow recommendations for two California streams and two major river systems in Montana.

Habitat Assessments and Habitat Suitability Curve Development: Principal investigator of a comparative habitat study evaluating limiting factors within the Clark Fork River, Montana. Applied a variety of habitat quantification methods including IFIM, Habitat Quality Index (HQI), Habitat Suitability Index system (HSI), and Trout Cover Rating (TCR). Project Manager of a comprehensive aquatic ecosystem assessment (conducted for the U.S. Fish and Wildlife Service) of the South Fork Coeur d'Alene River watershed, focused on evaluating factors controlling wild trout production. Collected, analyzed, and developed habitat suitability (Category II) curves for brown and brook trout, bull trout, chinook salmon, pink salmon, chum salmon, and steelhead trout. Invited participant in bull trout experts meeting to develop Habitat Suitability Curves (Category I) for bull trout spawning, juvenile rearing, adult holding, and fry. Organized and conducted three habitat suitability curve workshops designed to review and develop Category I curves for anadromous and resident salmonid species for drainages in Oregon and Idaho. Principal investigator of a microhabitat study to define habitat utilization of coho and chinook salmon, and steelhead trout in the White River, Washington; data were collected by direct observation using snorkeling techniques.

Endangered Species Issues: Direct experience in working on endangered species issues related to resource developments in California, Washington, Oregon Idaho, Montana, and North Carolina, including those that influence streamflow, temperature, habitat quality and quantity. Project Manager of technical studies on bull trout for Seattle Water Department (SWD); assisted in coordination of studies for integration into SWD Habitat Conservation Plan (HCP); represented SWD on ESA task force focused on listing status of species of special concern related to SWD facility operations. Project Manager for Tri-County Urban Issues ESA response project focused on evaluating restoration options for listed chinook salmon within urban watersheds. Project Manager of an HCP being developed for a gravel mine for the J.L. Storedahl & Sons Daybreak Mine located near the East Fork Lewis River, Washington, and more recently an HCP for the City of Kent, Washington water supply. Project Manager for development of restoration plans for reintroducing the federally listed endangered Snake River chinook salmon into the Panther Creek drainage in Idaho; worked with federal and state agencies in developing plan compatible with mandates of ESA and state and federal directives relative to reintroduction strategies. Project Manager for bull trout evaluation for the Seattle City Light in connection with the Boundary Hydroelectric Project and Ross Lake Project. Assessed Snake River salmon recovery plan options and mandates in the context of instream flow recommendations formulated on behalf of the Nez Perce Tribe, as part of the Snake River Basin Adjudication. Appointed by Washington Governor Gary Locke to serve on five member Independent Science Panel focused on salmon recovery in the State of Washington.

Fish Population Assessments: Directed numerous studies focused on determining fish population abundance and dynamics in streams and rivers. These have most recently included fish studies conducted for General Electric (Housatonic River, Massachusetts), the Seattle Water Department (Lake Chester Morse and Cedar watershed), Montana Power Company (Holter and Hauser reservoirs; Missouri River), Atlantic Richfield Company (Clark Fork River and tributaries), U.S. Fish and Wildlife Service (Coeur d'Alene basin and St. Regis Rivers), J.L. Storedahl Company (series of gravel ponds adjacent to the East Fork Lewis River), and Ketchikan Public Utilities (Whitman and Connell lakes, and tributaries (ongoing). Surveys often include use of a variety of gear types including electrofishing, seining, gill netting, trapping, hook and line, and snorkeling.

Fisheries Habitat Enhancement: Project manager for a mine reclamation fishery habitat enhancement project for the Bonneville Power Administration (BPA) for Panther Creek, Idaho; a fisheries engineering habitat enhancement project on the Yankee Fork of the Salmon River, Idaho, for the Shoshone-Bannock Indian Tribes; a habitat enhancement project on the East Fork Salmon River Idaho for the Shoshone-Bannock Tribes, a tributary improvement study for Pacific Gas and Electric Company (PG&E) in California; a feasibility study for developing an artificial spawning channel in Montana; a gravel supplementation study to evaluate options for increasing brown and rainbow trout spawning success within the Madison River below Madison Dam (for Montana Power Company); and most recently, development of habitat restoration options designed to restore runs of chinook salmon back to Panther Creek (conducted for NMFS). Enhancement measures included instream structures, bank stabilization, spawning channel development, spawning gravel supplementation, rearing pond development (low-technology and natural), and barrier removal, mine tailings pond stabilization, and dam removal.

Fish Passage: Developed a procedure for assessing fish passage problems at low head hydro projects. Evaluated passage problems and barrier potential (chinook salmon and steelhead) of the Lake Redding project in California. Developed conceptual designs of fish passage facilities for salmon (Atlantic salmon) at two hydro projects in Connecticut. Assessed barrier potential (chinook salmon and steelhead) of falls in two Idaho streams, and formulated plans for removal of an abandoned power dam in the East Fork Salmon River drainage in Idaho. Designed barrier analysis study for potential flow-dependent barriers located in Ward Creek, below Connell Dam near Ketchikan, Alaska. Involved in the development of concepts for upstream and downstream fish passage (steelhead trout) on the Carmel River in California. Reviewed and assessed suitability of upstream and downstream passage facilities for the Milford Dam on the Penobscot River.

Book and Manuscript Reviews: Technical manuscript reviewer for Fisheries, Rivers, Transactions of the American Fisheries Society, and the North American Journal of Fisheries Management. Has reviewed technical reports for the U.S. Fish and Wildlife Service, U.S. Geological Survey, the U.S. Forest Service, and various State resource agencies. Member of the Editorial Board for "Rivers," a journal focused on addressing instream flow issues. Published several formal reviews of books in "Rivers" and "Fisheries."

SELECTED PUBLICATIONS AND TECHNICAL REPORTS

Reiser, D.W., E. Greenberg, T. Helser, M. Branton, and K. Jenkins. (2004). In situ reproduction, abundance and growth of young-of-year and adult largemouth bass in a population exposed to polychlorinated biphenyls. Environmental Toxicology and Chemistry, Volume 23, No. 7.

Demko, D., A. Olson, M. Simpson, G. Kopp, and D. Reiser. 2003. Acoustic tracking technology and potential applications for salmonid research within the San Francisco Bay and Sacramento- San Joaquin Delta. Prepared for California Urban Water Agencies, Sacramento, California.

Reiser, D.W., D.F. Woodward, E. Jeanes, D. Harper, A. Farag., and E. Connor. (submitted). Defining the determinants of wild trout production in the South Fork Coeur d'Alene River, Idaho using a reference stream approach. Submitted to North American Journal of Fisheries Management.

Reiser, D. W. 2002. Effects of the White River Hydroelectric Project on water temperatures relative to chinook salmon life history requirements. Prepared by R2 Resource Consultants for Lake Tapps Task Force and Perkins Coie, Bellevue, Washington.

Reiser, D. W., M. Loftus, D. Chapin, E. Jeanes, and K. Oliver. 2001. Effects of water quality and Lake Level on the biology and habitat of selected fish species in Upper Klamath Lake. Report prepared by R2 Resource Consultants Inc. for Bureau of Indian Affairs, Portland, Oregon.

Connor, E., D. W. Reiser, E. Greenberg, S. Beck, and K. Binkley. 2001. Fisheries study of Chester Morse Lake, Masonry Pool, and major tributaries of the Cedar River Watershed, Washington. Report prepared by R2 Resource Consultants, Inc. for Seattle Public Utilities, Seattle, Washington.

DeVries, P., B. Kvam, S. Beck, D. Reiser, M. Ramey, C. Huang, and C. Eakin. 2001. Kerr Hydroelectric Project Lower Flathead River ramping rate study. Report prepared by R2 Resource Consultants, Inc. for Confederated Salish and Kootenai Tribes of the Flathead Nation

Reiser, D. W., M. P. Ramey, and P. DeVries. 1999. Development of options for the reintroduction and restoration of chinook salmon into Panther Creek, Idaho. Pages 565-581 *in* E. Knudsen, C. Steward, D. MacDonald, J. Williams, and D. Reiser, editors. Sustainable Fisheries Management – Pacific Salmon. Lewis Publishers, Boca Raton, Florida. 724 p.

Ramey, M. P., S. Beck, D. W. Reiser, and J. Templeton. 1999. Fish habitat evaluation with unsteady flow. *In* Proceedings of Water Power 99. Las Vegas, Nevada.

DeVries, P., D. W. Reiser, and M. P. Ramey. 1999. A proposed classification program for determining regional instream flow needs in Alberta. Report prepared by R2 Resource Consultants for Alberta Environmental Protection. 34 p.

Reiser, D. W., A. Olson, and K. Binkley. 1998. Sediment deposition in fry emergence traps, a confounding factor in estimating survival to emergence. N. Amer. Journal of Fisheries Management Vol. 18, No. 3, 713-719 p.

Reiser, D. W. 1998. Sediment in gravel bed rivers: ecological and biological considerations. Pages 199-228 *in* P. Klingeman, R. Beschta, P. Komar, and J. Bradley, editors. Gravel Bed Rivers in the Environment. Water Resources Publications, LLC.

Reiser, D. W. 1998. Why fish need water: life history strategies and habitat requirements of salmonid populations in the Snake, Salmon, and Clearwater River Basins of Idaho. Expert Report prepared for the Department of Justice, Denver, Colorado.

Reiser, D. W., E. Connor, K. Binkley, K. Lynch, and D. Paige. 1997. An evaluation of spawning habitat used by bull trout in the Cedar Watershed, Washington. *In* Proceedings of Friends of the Bull Trout Conference, Trout Unlimited, Calgary, Alberta.

Connor, E., D. W. Reiser, K. Binkley, K. Lynch, and D. Paige. 1997. Life history and ecology of an unexploited bull trout population in the Cedar River watershed, Washington. *In* Proceedings of Friends of the Bull Trout Conference, Trout Unlimited, Calgary, Alberta.

Reiser, D. W. 1996. Ecological and biological considerations in river restoration. Invited paper presented at ASCE conference, Anaheim, California. *In* Proceedings of 1996 North American Water and Environment Congress.

Reiser, D. W., M. P. Ramey, P. Cernera, and C. Richards. 1994. Conversion of remnant dredge mine ponds into chinook salmon rearing habitat: from feasibility to construction. Pages 208-225 *in* Proceedings of Rehabilitation of Inland Fisheries and Mass Removal of Fishes, University of Hull, North Humberside, UK.

Reiser, D. W., E. Connor, and K. Oliver. 1994. Evaluation of factors potentially limiting aquatic species abundance and distribution in the San Francisco/Sacramento-San Joaquin Estuary. Draft Report prepared by R2 Resource Consultants, Inc. for the California Urban Water Agencies, Sacramento, California.

Reiser, D. W., K. M. Binkley, and P. DeVries. 1994. Evaluation of potential effects of the proposed EPA salinity standard on the biological resources of the San Francisco/Sacramento – San Joaquin Estuary. Draft Report prepared by R2 Resource Consultants, Inc. for the California Urban Water Agencies, Sacramento, California.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids. Chapter 4 *in* W. Meehan, and R. Kendall, editors. Influences of Forest and rangeland management on salmonid fishes and their habitats. Spec. publication of the American Fisheries Society

Richards, C., P. Cernera, M. P. Ramey, and D. W. Reiser. 1992. Development of off-channel habitats for use by juvenile chinook salmon. N. Amer. Journal Fish Management. 12: 721-727.

CURRICULUM VITAE-- DR. CORREIGH M. GREENE

EDUCATION

Ph.D. 2001. Animal Behavior, University of California Davis.
M.S. 1995. Wildlife Ecology and Management, University of Michigan.
B.S. 1992. Environmental Studies and Biopsychology, Tufts University.

EMPLOYER

NOAA Fisheries, Northwest Fisheries Science Center, Environmental Conservation Division, Watersheds Program.

POSITION

Research Biologist.

CURRENT RESEARCH

My general research interests concern how individual condition influences population dynamics and distribution, and how knowledge of behavior and life history might aid in conservation. My research has focused on habitat use and habitat selection in a number of different wildlife species, including great gray owls, elk, and western fence lizards. I am currently studying biological habitat relationships, habitat selection, and life history variability of salmonid populations. My methods combine matrix modeling efforts, statistical analyses of time series population data, and empirical studies of ecology and behavior at juvenile and spawning life history stages in salmon.

PEER-REVIEWED PUBLICATIONS

Greene, C.M., and T.J. Beechie. 2004. Consequences of potential density-dependent mechanisms on recovery of ocean-type chinook salmon (*Oncorhynchus tshawytscha*). *Canadian Journal of Fisheries and Aquatic Sciences* **61:590-602.**

Greene, C.M. 2003. Habitat selection reduces extinction of populations subject to Allee effects. *Theoretical Population Biology*, 64:1-10.

Greene, C.M., Owings, D.H., Hart, L.A. and Klimley, A.P. 2002. Revisiting the Umwelt: Environments of animal communication. *Journal of Comparative Psychology*, 116: 115.

Rabin, L.A. and C.M. Greene. 2002. Changes to Acoustic Communication Systems in Human-Altered Environments. *Journal of Comparative Psychology*, 116: 137-141.

Howell, J.A., G.C. Brooks, M.Semenoff-Irving, and C.M. Greene. 2002. Population dynamics of tule elk at Point Reyes National Seashore, California. *Journal of Wildlife Management*, 66: 478-490.

Bell, A.M., J.M. Davis, C.M. Greene, S.C. Lema, J.V. Watters, and L.H. Yang. 2001. Evolutionary questions in an ecologically relevant context. *Evolution*, 55: 1715–1716.

Greene, C.M. and J.A. Stamps. 2001. Habitat selection at low population densities. *Ecology*, 82:2091-2100.

Greene, C.M. and R.G. Cook. 1997. Landmark geometry and identity controls spatial representation in rats. *Animal Learning and Behavior*, 25: 312-323.

Hanley, K.A., J.E. Biardi, C.M. Greene, T.M. Markowitz, C.E. O'Connell, and J.H. Hornberger. 1996. The behavioral ecology of host parasite interactions: An interdisciplinary challenge. *Parasitology Today*, 12:371-373.

MANUSCRIPTS IN REVIEW

Greene, C.M., D.W. Jensen, E. Beamer, G. Pess, and A. Steel. In review. Effects of stream, estuary, and ocean conditions on chinook salmon return rates in the Skagit River, WA. *Canadian Journal of Fisheries and Aquatic Sciences*.

BOOKS AND BOOK CHAPTERS

Greene, C.M. and P.M. Huntzinger, eds. 2001. *The Natural History of Stebbins Cold Canyon Reserve*. University of California Natural Reserve System, Davis, CA.

Greene, C.M., J.A. Umbanhowar, M. Mangel, and T. Caro. 1998. Animal breeding systems, hunter selectivity, and consumptive use in wildlife conservation. Pages 271-305 *in* T.M. Caro, ed., *Behavioral Ecology and Conservation Biology*, Oxford University Press, Oxford.

RESEARCH GRANTS

Kiffney, P., and C.M. Greene. 2003. Tributary hotspots: hotspots for biological diversity and productivity? Earthwatch Institute Grant.

Kiffney, P., C.M. Greene, G.R. Pess, and B. Sanderson. 2003. Tributary hotspots: hotspots for biological diversity and productivity? Northwest Fisheries Science Center Internal Grant, 2002: $45,000.

AWARDS

UC Davis Academic Senate Graduate Student Teaching Award, 1999.

FELLOWSHIPS

National Research Council Postdoctoral Research Associateship, 2001.
UC Davis Professors for the Future Fellowship, 2000.
Tracey and Ruth Risdon Storer Zoological Scholarship, 2000.
Center for Population Biology Research Training Grant Fellowship, 1999.

PRESENTATIONS AT REGIONAL, MEETINGS, AND SYMPOSIA

Beechie T.M., C.M. Greene, L. Holsinger, and E. Beamer. 2003. A Monte Carlo approach to evaluating spawning habitat limitations on salmon populations. Invited symposium talk at American Fisheries Society, Quebec City.

Greene, C.M., T.J. Beechie, and M. Ruckelshaus. 2003. Linking habitat-related and density-dependent population responses in chinook salmon. Puget Sound/Georgia Basin Conference, Vancouver, BC

Greene, C.M. 2002. A conceptual framework for integrating behavioral studies and conservation. Animal Behavior Society, Bloomington, IN.

Greene, C.M., M. Ruckelshaus, T. Beechie, and E. Beamer. 2002. Linking habitat-related and density-dependent population responses in Chinook salmon. Western Division of the American Fisheries Society, Spokane, WA.

Greene, C.M. 2001. Habitat selection stabilizes populations under an Allee effect. Society for Conservation Biology Conference, Hilo, HI.

Greene, C. M. 2000. Behavior in the not-so-natural world: The effects of habitat fragmentation on acoustic communication. Animal Behavior Research Training Group Conference on *Communication: The Animal in the Context of its Environment*, Davis, CA.

Greene, C. M., and J.A. Stamps 1998. Habitat selection under an Allee effect. International Society for Behavioral Ecology Conference, Monterey, CA.

Curriculum vitae
Timothy J. Beechie

Education
PhD, forest resources, 1998, University of Washington
MS, fisheries, 1990, University of Washington
BS, geology, 1983, University of Washington

Work Experience
1999-present
Research Fishery Biologist, Northwest Fisheries Science Center
Currently serving as Science Coordinator for the Center's Watershed Program, and Team Leader for the Ecosystems Processes Team. Research focuses on watershed processes and land uses affecting stream and estuarine habitats. Current research topics include patterns of temperature change in river networks, modeling recovery of wood recruitment as a function of stand type and management actions, floodplain dynamics and off-channel habitat formation in river networks, assessing the feasibility of restoring incised river channels in semi-arid regions, and relationships among hydrologic regime and salmon life history diversity.

1998-99
Senior Restoration Ecologist, Skagit System Cooperative (fisheries services for the Sauk-Suiattle, Upper Skagit, and Swinomish Indian tribes), La Conner, Washington
Director of Skagit System Cooperative's (SSC) Restoration Program. Responsibilities included development of a restoration program including a strategic approach to identifying salmon habitat restoration actions for the Skagit River basin, coordination of restoration inventory activities with other active groups in the Skagit River basin, coordination and oversight of employees and co-workers involved in researching salmon habitat biology, and oversight of research and restoration budgets.

1990-1998
Geomorphologist, Skagit System Cooperative, La Conner, Washington
Research and site reviews on interactions between salmonid habitat conditions and forest practices or other land uses, documenting relationships among watershed processes and salmonid habitats in streams (hydrologic analyses, assessments of habitat losses, watershed assessments), evaluation of timber harvest applications for potential impacts to salmonid habitat.

1983 to 1986
Fish Biologist / Geomorphologist, U.S. Peace Corps / Niger Fisheries Service, Tabalack, Niger and Niamey, Niger
Designed and conducted catch assessment survey for Lake Tabalack and Kehehe fisheries; characterized fish populations with experimental fishing gears; assessed physical and chemical characteristics of lakes, and social and economic factors affecting the commercial fishery; developed specific recommendations for management of the fishery; trained Niger co-workers to continue the monitoring of fishery. Also served as geomorphologist on three-person habitat classification team: surveyed and defined geologic and land-form zones that were the basis for hierarchical classification of wildlife habitats in "W" National Wildlife Park.

Recent Publications

Beechie, T.J., M. Liermann, E.M. Beamer, and R. Henderson. In press. A classification of large river habitat types and their use by juvenile salmon and trout. Transactions of the American Fisheries Society.

Beechie, T.J., C.N. Veldhuisen, D.E. Schuett-Hames, P. DeVries, R.H. Conrad, E.M. Beamer. In press. Monitoring treatments to reduce sediment and hydrologic effects from roads. In P.Roni, editor. Methods for monitoring stream and watershed restoration.

Pollock, M.M., T.J. Beechie, S. Chan, and R. Bigley. In press. Monitoring and evaluating riparian restoration efforts. In P.Roni, editor. Methods for monitoring stream and watershed restoration.

Greene, C.M., and T.J. Beechie. 2004. Habitat-specific population dynamics of ocean-type chinook salmon (Onchorynchus tshawytscha) in Puget Sound. Canadian Journal of Fisheries and Aquatic Sciences 61:590-602.

Hyatt, T. L., T.Z. Waldo, and T.J. Beechie. 2004. A watershed-scale assessment of riparian forests, with implications for restoration. Restoration Ecology 12:175-183.

Kiffney, P. M., C. J. Volk, T. J. Beechie, G. L. Murray, G. L. Pess, and R. E. Edmonds. 2004. A high-severity disturbance event alters community and ecosystem properties in West Twin Creek, Olympic National Park, Washington, USA. American Midland Naturalist 152:268-303.

Pollock, M. M., G. R. Pess, T. J. Beechie, and D. R. Montgomery. 2004. The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA. North American Journal of Fisheries Management 24:749-760.

Beechie, T.J., E.A. Steel, P.R. Roni, and E. Quimby, editors. 2003. Ecosystem recovery planning for listed salmon: an integrated assessment approach. NOAA Technical Memorandum, National Marine Fisheries Service, Seattle, Washington.

Pess, G.R., T.J. Beechie, J.E. Williams, D.R. Whitall, J.I. Lange, and J.R. Klochak. 2003. Watershed assessment techniques and the success of aquatic restoration activities. Pages 185-2001 In R. Wissmar and P. Bisson, eds. Strategies for restoring river ecosystems: sources of variability and uncertainty in natural and managed systems. American Fisheries Society, Bethesda, MD.

Beechie, T.J., G. Pess, E. Beamer, G. Lucchetti, and R.E. Bilby. 2002. Role of watershed assessments in recovery planning for endangered salmon. Pages 194-225 in D. Montgomery, S. Bolton, D. Booth, and L. Wall, editors, Restoration of Puget Sound Rivers, University of Washington Press, Seattle.

Pess, G., D.R. Montgomery, T.J. Beechie, and L. Holsinger. 2002. Anthropogenic alterations to the biogeography of Puget Sound salmon. Pages 129-154 in D. Montgomery, S. Bolton, D. Booth, and L. Wall, editors, Restoration of Puget Sound Rivers, University of Washington Press, Seattle.

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A review of site-specific restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 22:1-20.

Welty, J.T. T.J. Beechie, K. Sullivan, D.M. Hyink, R.E. Bilby, C. Andrus, G. Pess. 2002. Riparian Aquatic Interaction Simulator (RAIS): a model of riparian forest dynamics for the generation of large woody debris and shade. Forest Ecology and Management 162:299-318.

Beechie, T. 2001. Empirical predictors of bedload annual travel distance, and implications for stream habitat recovery. Earth Surface Processes and Landforms 26:1025-1034.

Beechie, T.J., B.D. Collins, and G.R. Pess. 2001. Holocene and recent geomorphic processes, land use and salmonid habitat in two north Puget Sound river basins. Pages 37-54 In J.B. Dorava, D.R. Montgomery, F. Fitzpatrick, and B. Palcsak, eds. Geomorphic processes and riverine habitat, Water Science and Application Volume 4, American Geophysical Union, Washington D.C.

Beechie, T., S. Bolton, G. Pess, R. Bilby, and P. Kennard. 2000. Rates and pathways of recovery for woody debris recruitment in northwestern Washington streams. North American Journal of Fisheries Management. 20:436–452.

Beechie, T. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. Fisheries 24(4):6-15.

A Statistical Model Of Central Valley Chinook Incorporating Uncertainty: Signature

This proposal is for the Science Program 2004 solicitation as prepared by Lawrence, Cathy .

2004-12-27: In response to user feedback, the project and conflict of interest forms have been corrected. Please read the current versions carefully.

The applicant for this proposal must submit this form by printing it, signing below, and faxing it to +1 877-408-9310.

Failure to sign and submit this form will result in the application not being considered for funding.

The individual signing below declares that:

- all representations in this proposal are truthful;
- the individual signing the form is authorized to submit the application on behalf of the applicant (if applicant is an entity or organization);
- the applicant has read and understood the conflict of interest and confidentiality discussion under the Confidentiality and Conflict of Interest Section in the main body of the PSP and waives any and all rights to privacy and confidentiality1 of the proposal on behalf of the applicant, to the extent provided in this PSP; and
- the applicant has read and understood all attachments of this PSP.

Proposal Title: A Statistical Model of Central Valley Chinook Incorporating Uncertainty
Proposal Number: 2004.01-0214
Submitter: Lawrence, Cathy (clawrence@ucdavis.edu)

Rene Domino, CRA　　　　1-3-05

Applicant Signature　　　　**Date**

Rene H. Domino, CRA
Contracts & Grants Analyst

Printed Name Of Applicant

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
Office of Sponsored Programs
One Shields Avenue, 118 Everson Hall
DAVIS, CALIFORNIA 95616-8671

Applicant Organization

UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

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January 3, 2005

Ms. Kate Marie, Grant Manager
Science Program
California Bay-Delta Authority
650 Capitol Mall, 5th Floor
Sacramento CA 95814

Dear Ms. Marie:

Letter in Support of Project # 2004-12-27, Entitled: **"A Statistical Model of Central Valley Chinook Incorporating Uncertainty"**
UC Davis Principal Investigator- Dr. Louis (Loo) Botsford

It is our pleasure to forward institutional support and approval of the collaboration by UCD's Dr. Botsford on the referenced research project to the California Bay-Delta Authority Science Program.

Please note as outlined in Attachments 3 and 6 of the Solicitation we would like to address the Compliance with Standard Terms and Conditions section in order to provide notification that UCD takes exception to the following proposed "standard" clauses:

Exhibit C – Section 12 – State Travel & Per Diem Expenses Guidelines (Delete)
Exhibit C – General Terms and Conditions for ERP Grants (Replace with GIA 101)
Exhibit C – Special Terms and Conditions for ERP Grants (Replace with UC IP Clause)

Please note the above has previously been negotiated with CALFED/GCAPS on behalf of the University of California and agreeable language has been included in the following current ERP agreements with UC Davis (ERP-02D-P31, ERP-02D-P32, ERP-02D-P33, ERP-02D-P35, and ERP-02D-P51).

Should the Department make an award to the University, we would anticipate negotiating terms that comply with University and federal guidelines as they pertain to the higher learning institutions and retention of intellectual property rights.

Please contact the principal investigator for scientific information. Administrative questions may be directed to me by telephone, facsimile or electronic mail at the numbers cited above.

Sincerely,

René H. Domino, CRA
Contracts & Grants Analyst

cc: Dr. L. Botsford